QUANTUM - AND CLASSICAL COMPUTATION IN TGD UNIVERSE

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0.1 PREFACE

Brief summary of TGD

Towards the end of the year 2023 I became convinced that it would be appropriate to prepare collections about books related to TGD and its applications. The finiteness of human lifetime was my first motivation. My second motivation was the deep conviction that TGD will mean a revolution of the scientific world view and I must do my best to make it easier.

The first collection would relate to the TGD proper and its applications to physics. Second collection would relate to TGD inspired theory of consciousness and the third collection to TGD based quantum biology. The books in these collections would focus on much more precise topics than the earlier books and would be shorter. This would make it much easier for the reader to understand what TGD is, when the time is finally mature for the TGD to be taken seriously. This particular book belongs to a collection of books about TGD proper.

The basic ideas of TGD

TGD can be regarded as a unified theory of fundamental interactions but is not the kind of unified theory as so called GUTs constructed by graduate students in the seventies and eighties using detailed recipes for how to reduce everything to group theory. Nowadays this activity has been completely computerized and it probably takes only a few hours to print out the predictions of this kind of unified theory as an article in the desired format. TGD is something different and I am not ashamed to confess that I have devoted the last 45 years of my life to this enterprise and am still unable to write The Rules.

If I remember correctly, I got the basic idea of Topological Geometrodynamics (TGD) during autumn 1977, perhaps it was October. What I realized was that the representability of physical space-times as 4-dimensional surfaces of some higher-dimensional space-time obtained by replacing the points of Minkowski space with some very small compact internal space could resolve the conceptual difficulties of general relativity related to the definition of the notion of energy. This belief was too optimistic and only with the advent of what I call zero energy ontology the understanding of the notion of Poincare invariance has become satisfactory. This required also the understanding of the relationship to General Relativity.

It soon became clear that the approach leads to a generalization of the notion of space-time with particles being represented by space-time surfaces with finite size so that TGD could be also seen as a generalization of the string model. Much later it became clear that this generalization is consistent with conformal invariance only if space-time is 4-dimensional and the Minkowski space factor of the embedding space is 4-dimensional. During last year it became clear that 4-D Minkowski space and 4-D complex projective space CP_2 are completely unique in the sense that they allow twistor space with Kähler structure.

It took some time to discover that also the geometrization of also gauge interactions and elementary particle quantum numbers could be possible in this framework: it took two years to find the unique internal space (CP_2) providing this geometrization involving also the realization that family replication phenomenon for fermions has a natural topological explanation in TGD framework and that the symmetries of the standard model symmetries are much more profound than pragmatic TOE builders have believed them to be. If TGD is correct, the mainstream particle physics chose the wrong track leading to the recent deep crisis when people decided that quarks and leptons belong to the same multiplet of the gauge group implying instability of the proton.

Instead of trying to describe in detail the path, which led to TGD as it is now with all its side tracks, it is better to summarize the recent view which of course need not be final.

TGD can be said to be a fusion of special and general relativities. The Relativity Principle (Poincare Invariance) of Special Relativity is combined with the General Coordinate Invariance and Equivalence Principle of General Relativity. TGD involves 3 views of physics: physics geometry, physics as number theory and physics as topological physics in some sense.

Physics as geometry

"Geometro-" in TGD refers to the idea about the geometrization of physics. The geometrization program of Einstein is extended to gauge fields allowing realization in terms of the geometry of surfaces so that Einsteinian space-time as abstract Riemann geometry is replaced with sub-manifold geometry. The basic motivation is the loss of classical conservation laws in General Relativity Theory (GRT)(see **Fig. 12**). Also the interpretation as a generalization of string models by replacing string with 3-D surface is natural.

- Standard model symmetries uniquely fix the choice of 8-D space in which space-time surfaces live to $H = M^4 \times CP_2$ [L116]. Also the notion of twistor is geometrized in terms of surface geometry and the existence of twistor lift fixes the choice of H completely so that TGD is unique [L37, L48](see **Fig. 13**). The geometrization applies even to the quantum theory itself and the space of space-time surfaces - "world of classical worlds" (WCW) - becomes the basic object endowed with Kähler geometry (see **Fig. 14**). The mere mathematical existence of WCW geometry requires that it has maximal isometries, which together twistor lift and number theoretic vision fixes it uniquely [L118].

- General Coordinate Invariance (GCI) for space-time surfaces has dramatic implications. A given 3-surface fixes the space-time surface almost completely as analog of Bohr orbit (preferred extremal). This implies holography and leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K113, L52].

- From the beginning it was clear that the theory predicts the presence of long ranged classical electro-weak and color gauge fields and that these fields necessarily accompany classical electromagnetic fields in all scales. It took about 26 years to gain the maturity to admit the obvious: these fields are classical correlates for long range color and weak interactions assignable to the phases of ordinary matter predicted by the number theoretic vision and behaving like dark matter but identifiable as matter explaining the missing baryon problem whereas the galactic dark matter would correspond to the dark energy assignable monopole flux tubes as deformations of cosmic strings. The only possible conclusion is that TGD physics is a fractal consisting of an entire hierarchy of fractal copies of standard model physics. Also the understanding of electro-weak massivation and screening of weak charges has been a long standing problem and p-adic physics solved this problem in terms of p-adic thermodynamics [K24, K55] [L98].

- One of the most recent discoveries of classical TGD is exact general solution of the field equations. Holography can be realized as a generalized holomorphy realized in terms of what I call Hamilton-Jacobi structure [L107]. Space-time surfaces correspond to holomorphic imbeddings of the space-time surface to H with a generalized complex structure defined by the vanishing of 2 analytic functions of 4 generalized complex coordinates of H. These surfaces are automatically minimal surfaces. This is true for any geneneral coordinate invariant action constructed in terms of the induced geometric structures so that the dynamics is universal. Different actions differ only in the sense that singularities at which the minimal surface property fails depend on the action. This affects the scattering amplitudes, which can be constructed in terms of the data related to the singularities [L129].

- Generalized conformal symmetries define an extension of conformal symmetries and one can assign to them Noether charges. Besides this the so called super-symplectic symmetries associated with $\delta M^4_+ \times CP_2$ define isometries of the "world of classical worlds" (WCW), which by holography is essentially the space of Bohr orbits of 3-surfaces as particles so that quantum TGD is expected to reduce to a generalization of wave mechanics.

Physics as number theory

During these years TGD led to a rather profound generalization of the space-time concept. Quite general properties of the theory led to the notion of many-sheeted space-time with sheets representing physical subsystems of various sizes. At the beginning of 90s I became dimly aware of the importance of p-adic number fields and soon ended up with the idea that p-adic thermodynamics for a conformally invariant system allows to understand elementary particle massivation with amazingly few input assumptions. The attempts to understand p-adicity from basic principles led gradually to the vision about physics as a generalized number theory as an approach complementary to the physics as an infinite-dimensional spinor geometry of WCW approach. One of its elements was a generalization of the number concept obtained by fusing real numbers and various p-adic numbers along common rationals. The number theoretical trinity involves besides p-adic number fields also quaternions and octonions and the notion of infinite prime.

Adelic physics [L34, L35] fusing real and various p-adic physics is part of the number theoretic vision, which provides a kind of dual description for the description based on space-time geometry and the geometry of "world of classical words". Adelic physics predicts two fractal length scale hierarchies: p-adic length scale hierarchy and the hierarchy of dark length scales labelled by $h_{eff} = nh_0$, where n is the dimension of extension of rational. The interpretation of the latter hierarchy is as phases of ordinary matter behaving like dark matter. Quantum coherence is possible in arbitarily long scales. These two hierarchies are closely related. p-Adic primes correspond to ramified primes for a polynomial, whose roots define the extension of rationals: for a given extension this polynomial is not unique.

$M^8 - H$ duality

The concrete realization of the number theoretic vision is based on $M^8 - H$ duality (see **Fig. 15**). What the precise form is this duality is, has been far from clear but the recent form is the simplest one and corresponds to the original view [L121]. M^8 corresponds to octonions O but with the number theoretic metric defined by $Re(o^2)$ rather than the standard norm and giving Minkowskian signature.

The physics in M^8 can be said to be algebraic whereas in H field equations are partial differential equations. The dark matter hierarchy corresponds to a hierarchy of algebraic extensions of rationals inducing that for adeles and has interpretation as an evolutionary hierarchy (see **Fig. 16**). p-Adic physics is an essential part of number theoretic vision and the space-time surfaces are such that at least their M^8 counterparts exists also in p-adic sense. This requires that the analytic function defining the space-time surfaces are polynomials with rational coefficients.

M^8-H duality relates two complementary visions about physics (see **Fig. 17**), and can be seen as a generalization of the momentum-position duality of wave mechanics, which fails to generalize to quantum field theories (QFTs). M^8-H duality applies to particles which are 3-surfaces instead of point-like particles.

p-Adic physics

The idea about p-adic physics as physics of cognition and intentionality emerged also rather naturally and implies perhaps the most dramatic generalization of the space-time concept in which most points of p-adic space-time sheets are infinite in real sense and the projection to the real imbedding space consists of discrete set of points. One of the most fascinating outcomes was the observation that the entropy based on p-adic norm can be negative. This observation led to the vision that life can be regarded as something in the intersection of real and p-adic worlds. Negentropic entanglement has interpretation as a correlate for various positively colored aspects of conscious experience and means also the possibility of strongly correlated states stable under state function reduction and different from the conventional bound states and perhaps playing key role in the energy metabolism of living matter.

If one requires consistency of Negentropy Mazimization Principle with standard measurement theory, negentropic entanglement defined in terms of number theoretic negentropy is necessarily associated with a density matrix proportional to unit matrix and is maximal and is characterized by the dimension n of the unit matrix. Negentropy is positive and maximal for a p-adic unique prime dividing n.

Hierarchy of Planck constants labelling phases ordinary matter dark matter behaving like dark matter

One of the latest threads in the evolution of ideas is not more than nine years old. Learning about the paper of Laurent Nottale about the possibility to identify planetary orbits as Bohr orbits with a gigantic value of gravitational Planck constant made once again possible to see the obvious. Dynamical quantized Planck constant is strongly suggested by quantum classical correspondence and the fact that space-time sheets identifiable as quantum coherence regions can have arbitrarily large sizes. Second motivation for the hierarchy of Planck constants comes from bio-electromagnetism suggesting that in living systems Planck constant could have large values making macroscopic quantum coherence possible. The interpretation of dark matter as a hierarchy of phases of ordinary matter characterized by the value of Planck constant is very natural.

During summer 2010 several new insights about the mathematical structure and interpretation of TGD emerged. One of these insights was the realization that the postulated hierarchy of Planck constants might follow from the basic structure of quantum TGD. The point is that due to the extreme non-linearity of the classical action principle the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is one-to-many and the natural description of the situation is in terms of local singular covering spaces of the imbedding space. One could speak about effective value of Planck constant $h_{eff} = n \times h$ coming as a multiple of minimal value of Planck constant. Quite recently it became clear that the non-determinism of Kähler action is indeed the fundamental justification for the hierarchy: the integer n can be also interpreted as the integer characterizing the dimension of unit matrix characterizing negentropic entanglement made possible by the many-sheeted character of the space-time surface.

Due to conformal invariance acting as gauge symmetry the n degenerate space-time sheets must be replaced with conformal equivalence classes of space-time sheets and conformal transformations correspond to quantum critical deformations leaving the ends of space-time surfaces invariant. Conformal invariance would be broken: only the sub-algebra for which conformal weights are divisible by n act as gauge symmetries. Thus deep connections between conformal invariance related to quantum criticality, hierarchy of Planck constants, negentropic entanglement, effective p-adic topology, and non-determinism of Kähler action perhaps reflecting p-adic non-determinism emerges.

The implications of the hierarchy of Planck constants are extremely far reaching so that the significance of the reduction of this hierarchy to the basic mathematical structure distinguishing between TGD and competing theories cannot be under-estimated.

TGD as an analog of topological QFT

Consider next the attribute "Topological". In condensed matter physical topological physics has become a standard topic. Typically one has fields having values in compact spaces, which are topologically non-trivial. In the TGD framework space-time topology itself is non-trivial as also the topology of $H = M^4 \times CP_2$. Since induced metric is involved with TGD, it is too much to say that TGD is topological QFT but one can for instance say, that space-time surfaces as preferred extremals define representatives for 4-D homological equivalence classes.

The space-time as 4-surface $X^4 \subset H$ has a non-trivial topology in all scales and this together with the notion of many-sheeted space-time brings in something completely new. Topologically trivial Einsteinian space-time emerges only at the QFT limit in which all information about topology is lost (see **Fig. 18**).

Any GCI action satisfying holography=holomorphy principle has the same universal basic extremals: CP_2 type extremals serving basic building bricks of elementary particles, cosmic strings and their thickenings to flux tubes defining a fractal hierarchy of structure extending from CP_2 scale to cosmic scales, and massless extremals (MEs) define space-time correletes for massless particles. World as a set or particles is replaced with a network having particles as nodes and flux tubes as bonds between them serving as correlates of quantum entanglement.

"Topological" could refer also to p-adic number fields obeying p-adic local topology differing radically from the real topology (see **Fig. 19**).

Zero energy ontology

TGD inspired theory of consciousness entered the scheme after 1995 as I started to write a book about consciousness. Gradually it became difficult to say where physics ends and consciousness theory begins since consciousness theory could be seen as a generalization of quantum measurement theory by identifying quantum jump as a moment of consciousness and by replacing the observer with the notion of self identified as a system which is conscious as long as it can avoid entanglement with environment. The somewhat cryptic statement "Everything is conscious and consciousness can be only lost" summarizes the basic philosophy neatly.

General coordinate invariance leads to the identification of space-time surfaces are analogous to Bohr orbits inside causal diamond (CD). CD obtained as intersection of future and past directed light-cones (with CP_2 factor included). By the already described hologamphy, 3-dimensional data replaces the boundary conditions at single 3-surface involving also normal derivatives with conditions involving no derivates.

In zero energy ontology (ZEO), the superpositions of space-time surfaces inside causal diamond (CD) having their ends at the opposite light-like boundaries of CD, define quantum states. CDs form a scale hierarchy (see **Fig. 20** and **Fig. 21**). Quantum states are modes of WCW spinor fields, essentially wave functions in the space WCW consisting of Bohr orbit-like 4-surfaces.

Quantum jumps occur between these and the basic problem of standard quantum measurement theory disappears. Ordinary state function reductions (SFRs) correspond to "big" SFRs (BSFRs) in which the arrow of time changes (see **Fig. 22**). This has profound thermodynamic implications and the question about the scale in which the transition from classical to quantum takes place becomes obsolete. BSFRs can occur in all scales but from the point of view of an observer with an opposite arrow of time they look like smooth time evolutions.

In "small" SFRs (SSFRs) as counterparts of "weak measurements" the arrow of time does not change and the passive boundary of CD and states at it remain unchanged (Zeno effect).

Equivalence Principle in TGD framework

There have been also longstanding problems related to the relationship between inertial mass and gravitational mass, whose identification has been far from obvious.

- Gravitational energy is well-defined in cosmological models but is not conserved. Hence the conservation of the inertial energy does not seem to be consistent with the Equivalence Principle. In this framework the quantum numbers are assigned with zero energy states located at the boundaries of CDs defined as intersections of future and past directed light-cones. The notion of energy-momentum becomes length scale dependent since one has a scale hierarchy for causal diamonds. This allows to understand the non-conservation of energy as apparent.

  Equivalence Principle in the form expressed by Einstein's equations follows from Poincare invariance once it is realized that GRT space-time is obtained from the many-sheeted space-time of TGD by lumping together the space-time sheets to a regionof Minkowski space and endowing it with an effective metric given as a sum of Minkowski metric and deviations of the metrices of space-time sheets from Minkowski metric. Similar description relates classical gauge potentials identified as components of induced spinor connection to Yang-Mills gauge potentials in GRT space-time. Various topological inhomogenities below resolution scale identified as particles are described using energy momentum tensor and gauge currents.

  At quantum level, the Equivalence Principle has a surprisingly strong content. In linear Minkowski coordinates, space-time projection of the M^4 spinor connection representing gravitational gauge potentials the coupling to induced spinor fields vanishes. Also the modified Dirac action for the solutions of the modified Dirac equation seems to vanish identically and in TGD perturbative approach separating interaction terms is not possible.

  The modified Dirac equation however fails at the singularities of the minimal surface representing space-time surface and Dirac action reduces to an integral over singularities for the trace of the second fundamental form slashed between the induced spinor field and its conjugate. Also the M^4 part of the trace is non-vanishing and gives rise to the gravitational coupling. The trace gives both standard model vertices and graviton emission vertices. One could say that at the quantum level gravitational and gauge interactions are eliminated everywhere except at the singularities identifiable as defects of the ordinary smooth structure. The exotic smooth structures [L86], possible only in dimension 4, are ordinary smooth structures apart from these defects serving as vertex representing a creation of a fermion-antifermion pair in the induced gauge potentials. The vertex is universal and essentially the trace of the second fundamental form as an analog of the Higgs field and the gravitational constant is proportional to the square of CP_2 radius.

- There is a delicate difference between inertial and gravitational masses. One can assume that the modes of the imbedding space spinor fields are solutions of massles Dirac equation in either $M^4 \times CP_2$ and therefore eigenstates of inertial momentum or in $CD = cd \times CP_2$: in this case they are only mass eigenstates. The mass spectra are identical for these options. Inertial momenta correspond naturally to the Poincare charges in the space of CDs. For the CD option the spinor modes correspond to mass squared eigenstates for which the mode for H^3 with a given value of light-proper time is a unitary irreducible $SO(1,3)$ representation rather than a representation of translation group. These two eigenmode basis correspond to gravitational basis for spinor modes.

Quantum TGD as a generalization of Einstein's geometrization program

I started the serious attempts to construct quantum TGD after my thesis around 1982. The original optimistic hope was that path integral formalism or canonical quantization might be enough to construct the quantum theory but it turned that this approach fails due to the extreme non-linearity of the theory.

It took some years to discover that the only working approach is based on the generalization of Einstein's program. Quantum physics involves the geometrization of the infinite-dimensional "world of classical worlds" (WCW) identified as the space of 3-dimensional surfaces. Later 3-surfaces where replaced with 4-surfaces satifying holography and therefore as analogs of Bohr orbits.

- If one assumes Bohr orbitology, then strong correlations between the 3-surfaces at the ends of CD follow and mean holography. It is natural to identify the quantum states of the Universe (and sub-Univeverses) as modes of a formally classical spinor field in WCW. WCW gamma matrices are expressible in terms of oscillator operators of free second quantized spinor fields of H. The induced spinor fields identified projections of H spinor fields to the space-time surfaces satisfy modified Dirac equation for the modified Dirac equation. Only quantum jump remains the genuinely quantal aspect of quantum physics.

- Quantum TGD can be seen as a theory for free spinor fields in WCW having maximal isometries and the generalization of the Super Virasoro conditions gives rise to the analog massless Dirac equation at the level of WCW.

The world of classical worlds and its symmetries

The notion of "World of Classical Worlds" (WCW) emerged around 1985 but found its basic form around 1990. Holography forced by the realization of General Coordinate Invariance forced/allowed to give up the attempts to make sense of the path integral.

A more concrete way to express this view is that WCW does not consist of 3-surfaces as particle-like entities but almost deterministic Bohr orbits assignable to them as preferred extremals of Kähler action so that quantum TGD becomes wave mechanics in WCW combined with Bohr orbitology. This view has profound implications, which can be formulated in terms of zero energy ontology (ZEO), solving among other things the basic paradox of quantum measurement theory. ZEO forms also the backbone of TGD inspired theory of consciousness and quantum biology.

WCW geometry exists only if it has maximal isometries: this statement is a generalization of the discovery of Freed for loop space geometries [A8]. I have proposed [K50, K25, K111, K84, L118] that WCW could be regarded as a union of generalized symmetric spaces labelled by zero modes which do not contribute to the metric. The induced Kähler field is invariant under symplectic transformations of CP_2 and would therefore define zero mode degrees of freedom if one assumes that WCW metric has symplectic transformations as isometries. In particular, Kähler magnetic fluxes would define zero modes and are quantized closed 2-surfaces. The induced metric appearing in Kähler action is however not zero mode degree of freedom. If the action contains volume term, the assumption about union of symmetric spaces is not well-motivated.

Symplectic transformations are not the only candidates for the isometries of WCW. The basic picture about what these maximal isometries could be, is partially inspired by string models.

- A weaker proposal is that the symplectomorphisms of H define only symplectomorphisms of WCW. Extended conformal symmetries define also a candidate for isometry group. Remarkably, light-like boundary has an infinite-dimensional group of isometries which are in 1-1 correspondence with conformal symmetries of $S^2 \subset S^2 \times R_+ = \delta M^4_+$.

- Extended Kac Moody symmetries induced by isometries of δM^4_+ are also natural candidates for isometries. The motivation for the proposal comes from physical intuition deriving from string models. Note they do not include Poincare symmetries, which act naturally as isometries in the moduli space of causal diamonds (CDs) forming the "spine" of WCW.

- The light-like orbits of partonic 2-surfaces might allow separate symmetry algebras. One must however notice that there is exchange of charges between interior degrees of freedom and partonic 2-surfaces. The essential point is that one can assign to these surface conserved charges when the dual light-like coordinate defines time coordinate. This picture also assumes a slicing of space-time surface by by the partonic orbits for which partonic orbits associated with wormrhole throats and boundaries of the space-time surface would be special. This slicing would correspond to Hamilton-Jacobi structure.

- Fractal hierarchy of symmetry algebras with conformal weights, which are non-negative integer multiples of fundamental conformal weights, is essential and distinguishes TGD from string models. Gauge conditions are true only the isomorphic subalgebra and its commutator with the entire algebra and the maximal gauge symmetry to a dynamical symmetry with generators having conformal weights below maximal value. This view also conforms with p-adic mass calculations.

- The realization of the symmetries for 3-surfaces at the boundaries of CD and for light-like orbits of partonic 2-surfaces is known. The problem is how to extend the symmetries to the interior of the space-time surface. It is natural to expect that the symmetries at partonic orbits and light-cone boundary extend to the same symmetries.

After the developments towards the end of 2023, it seems that the extension of conformal and Kac-Moody symmetries of string models to the TGD framework is understood. What about symplectic symmetries, which were originally proposed as isometries of WCW? In this article this question is discussed in detail and it will be found that these symmetries act naturally on 3-D holographic data and one can identify conserved charges. By holography this is in principle enough and might imply that the actions of holomorphic and symplectic symmetry algebras are dual. Holography=holomorphy hypothesis is discussed also in the case of the modified Dirac equation.

About the construction of scattering amplitudes

From the point of view of particle physics the ultimate goal is of course a practical construction recipe for the S-matrix of the theory. I have myself regarded this dream as quite too ambitious taking into account how far-reaching re-structuring and generalization of the basic mathematical structure of quantum physics is required. After having made several guesses for what the counterpart of S-matrix could be, it became clear that the dream about explicit formulas is unrealistic before one has understood what happens in quantum jump.

- In ZEO [K113, L52] one must distinguish between "small" state function reductions (SSFRs) and "big" SFRs (BSFRs). BSFR is the TGD counterpart of the ordinary SFRs and the arrow of the geometric time changes in it. SSFR follows the counterpart of a unitary time evolution and the arrow of the geometric time is preserved in SSFR. The sequence of SSFRs is the TGD counterpart for the sequence of repeated quantum measurements of the same observables in which nothing happens to the state. In TGD something happens in SSFRs and this gives rise to the flow of consciousness. When the set of the observables measured in SSFR does not commute with the previous set of measured observables, BSFR occurs.

The evolution by SSFRs means that also the causal diamond changes. At quantum level one has a wave function in the finite-dimensional moduli space of CDs which can be said to form a spine of WCW [L113]. CDs form a scale hierarchy. SSFRs are preceded by a dispersion in the moduli space of CDs and SSFR means localization in this space.

- There are several S-matrix like entities. One can assign an analog of the S-matrix to each analog of unitary time evolution preceding a given SSFR. One can also assign an analog S-matrix between the eigenstate basis of the previous set of observables and the eigenstate basis of new observers: this S-matrix characterizes BSFR. One can also assign to zero energy states an S-matrix like entity between the states assignable to the two boundaries of CD. These S-matrix like objects can be interpreted as a complex square root of the density matrix representable as a diagonal and positive square root of density matrix and unitary S-matrix so that quantum theory in ZEO can be said to define a square root of thermodynamics at least formally.

In standard QFTs Feynman diagrams provide the description of scattering amplitudes. The beauty of Feynman diagrams is that they realize unitarity automatically via the so-called Cutkosky rules. In contrast to Feynman's original beliefs, Feynman diagrams and virtual particles are taken only as a convenient mathematical tool in quantum field theories. The QFT approach is however plagued by UV and IR divergences and one must keep mind open for the possibility that a genuine progress might mean opening of the black box of the virtual particle.

In the TGD framework this generalization of Feynman diagrams indeed emerges unavoidably.

- The counterparts of elementary particles can be identified as closed monopole flux tubes connecting two parallel Minkowskian space-time sheets and have effective ends which are Euclidean wormhole contacts. The 3-D light-like boundaries of wormhole contacts as orbits of partonic 2-surfaces.

  The intuitive picture is that the 3-D light-like partonic orbits replace the lines of Feynman diagrams and vertices are replaced by 2-D partonic 2-surfaces. A stronger condition is that fermion number is carried by light-like fermion lines at the partonic orbits, which can be identified as boundaries string world sheets.

- The localization of the nodes of induced spinor fields to 2-D string world sheets (and possibly also to partonic 2-surfaces) implies a stringy formulation of the theory analogous to stringy variant of twistor formalism with string world sheets having interpretation as 2-braids. In the TGD framework, the fermionic variant of twistor Grassmann formalism combined with the number theoretic vision [L80, L81] led to a stringy variant of the twistor diagrammatics.

- Fundamental fermions are off-mass-shell in the sense that their momentum components are real algebraic integers in an extension of rationals associated with the space-time surfaces inside CD with a momentum unit determined by the CD size scale. Galois confinement states that the momentum components are integer valued for the physical states.

- The twistorial approach suggests also the generalization of the Yangian symmetry to infinite-dimensional super-conformal algebras, which would determine the vertices and scattering amplitudes in terms of poly-local symmetries.

The twistorial approach is however extremely abstract and lacks a concrete physical interpretation. The holography=holomorphy vision led to a breakthough in the construction of the scattering amplitudes by solving the problem of identifying interaction vertices [L129].

1. The basic prediction is that space-time surfaces as analogs of Bohr orbits are holomorphic in a generalized sense and are therefore minimal surfaces. The minimal surface property fails at lower-dimensional singularities and the trace of the second fundamental form (SFF) analogous to acceleration associated with the Bohr orbit of the particle as 3-surface has a delta function like singularity but vanishes elsewhere.

2. The minimal surface property expressess masslessness for both fields and particles as 3-surfaces. At singularities masslessness property fails and singularities can be said to serve as sources which also in QFT define scattering amplitudes.

3. The singularities are analogs of poles and cuts for the 4-D generalization of the ordinary holomorphic functions. Also for the ordinary holomorphic functions the Laplace equation as analog massless field equation and expressing analyticity fails. Complex analysis generalizes to dimension 4.

4. The conditions at the singularity give a generalization of Newton's "F=ma"! I ended up where I started more than 50 years ago!

5. In dimension 4, and only there, there is an infinite number of exotic diff structures [**?**], which differ from ordinary ones at singularities of measure zero analogous to defects. These defects correspond naturally to the singularities of minimal surfaces. One can say that for the exotic diff structure there is no singularity.

6. Group theoretically the trace of the SFF can be regarded as a generalization of the Higgs field, which is non-vanishing only at the vertices and this is enough. Singularities take the role of generalized particle vertices and determine the scattering amplitudes. The second fundamental form contracted with the embedding space gamma matrices and slashed between the second quantized induced spinor field and its conjugate gives the universal vertex involving only fermions (bosons are bound states of fermions in TGD). It contains both gauge and gravitational contributions to the scattering amplitudes and there is a complete symmetry between gravitational and gauge interactions. Gravitational couplings come out correctly as the radius squared of CP_2 as also in the classical picture.

7. The study of the modified Dirac equation leads to the conclusion that vertices as singularities and defects contain the standard electroweak gauge contribution coming from the induced spinor connection and a contribution from the M^4 spinor connection. M^4 part of the generalized Higgs can give rise to a graviton as an $L = 1$ rotational state of the flux tube representing the graviton. It is not clear whether M^4 Kähler gauge potential can give rise to a spin 1 particle. The vielbein part of M^4 spinor connection is pure gauge and could give rise to gravitational topological field theory.

Figures

Basic ideas of TGD inspired quantum biology

The following list gives the basic elements of TGD inspired quantum biology.

- Many-sheeted space-time allows the interpretation of the structures of macroscopic world around us in terms of space-time topology. Magnetic/field body acts as intentional agent using biological body as a sensory receptor and motor instrument and controlling biological body and inheriting its hierarchical fractal structure. Fractal hierarchy of EEGs and its variants can be seen as communication and control tools of magnetic body. Also collective levels of consciousness have a natural interpretation in terms of magnetic body. Magnetic body makes also possible entanglement in macroscopic length scales. The braiding of magnetic flux tubes makes possible topological quantum computations and provides a universal mechanism of memory. One can also undersand the real function of various information molecules and corresponding receptors by interpreting the receptors as addresses in quantum computer memory and information molecules as ends of flux tubes which attach to these receptors to form a connection in quantum web.

  Note that also the notion of electric body makes sense [L100]. Quite generally, long range classical gravitational, electric and magnetic fields give rise to very large values of effective Planckl constants. The Nottale's hypothesis of gravitational Planck constant generalizes to electric interactions.

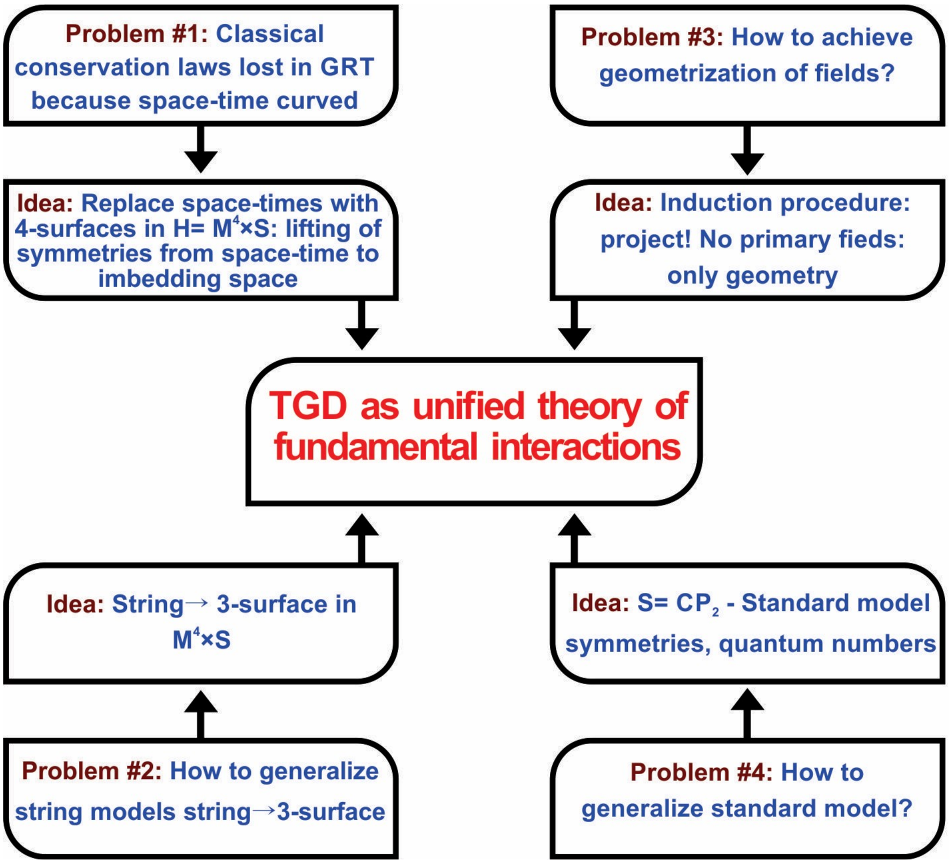


Figure 1: The problems leading to TGD as their solution.

- Magnetic body carrying dark matter and forming an onion-like structure with layers characterized by large values of Planck constant is the key concept of TGD inspired view about Quantum Mind to biology.. Magnetic body is identified as intentional agent using biological body as sensory receptor and motor instrument. EEG and its fractal variants are identified as a communication and control tool of the magnetic body and a fractal hierarchy of analogs of EEG is predicted. Living system is identified as a kind of Indra's net with biomolecules representing the nodes of the net and magnetic flux tubes connections between then.

  The reconnection of magnetic flux tubes and phase transitions changing Planck constant and therefore the lengths of the magnetic flux tubes are identified as basic mechanisms behind DNA replication and analogous processes and also behind the phase transitions associated with the gel phase in cell interior. The braiding of magnetic flux makes possible universal memory representation recording the motions of the basic units connected by flux tubes. Braiding also defines topological quantum computer programs updated continually by the flows of the basic units. The model of DNA as topological quantum computer is discussed as an application. In zero energy ontology the braiding actually generalize to 2-braiding for string world sheets in 4-D space-time and brings in new elements.

- Zero energy ontology (ZEO) makes possible the proposed p-adic description of intentions and cognitions and their transformations to action. Time mirror mechanism based on sending of negative energy signal to geometric past would apply to both long term memory recall, remote metabolism, and realization of intentional acting as an activity beginning in the geometric past in accordance with the findings of Libet. ZEO gives a precise content to the notion of negative energy signal in terms of zero energy state for which the arrow of geometric time is opposite to the standard one.

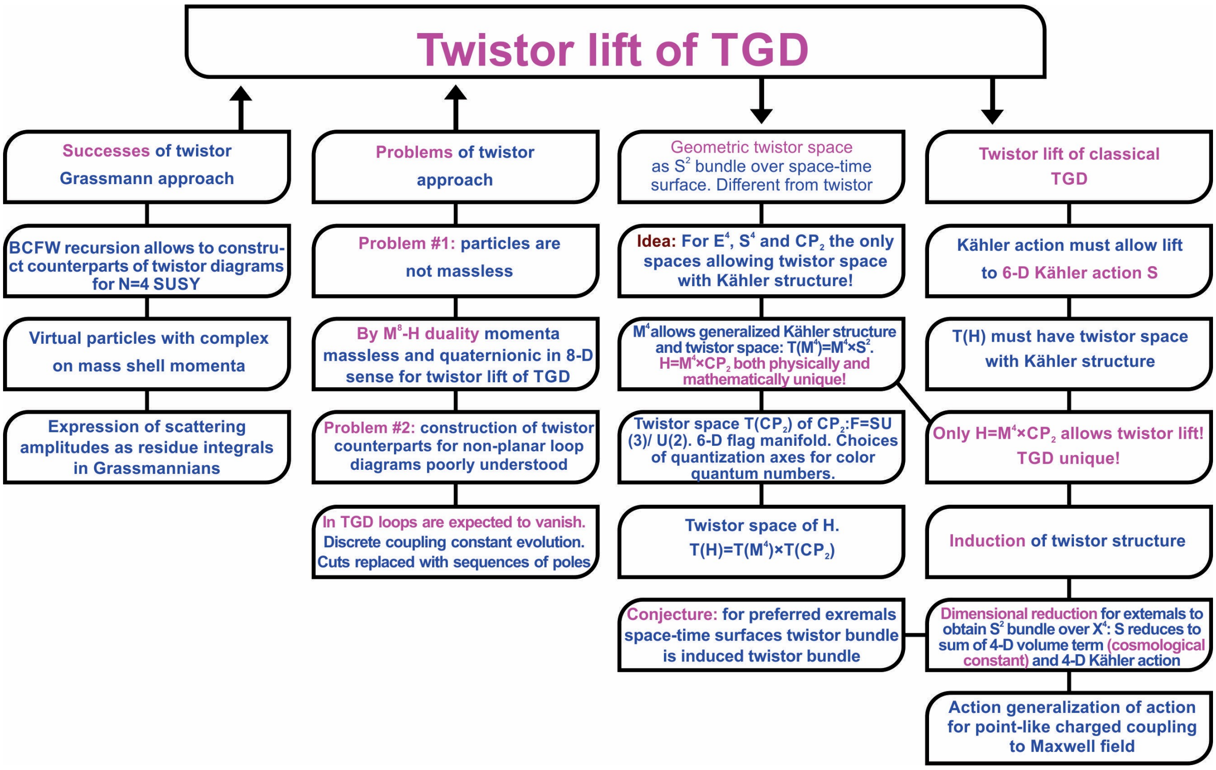


Figure 2: Twistor lift

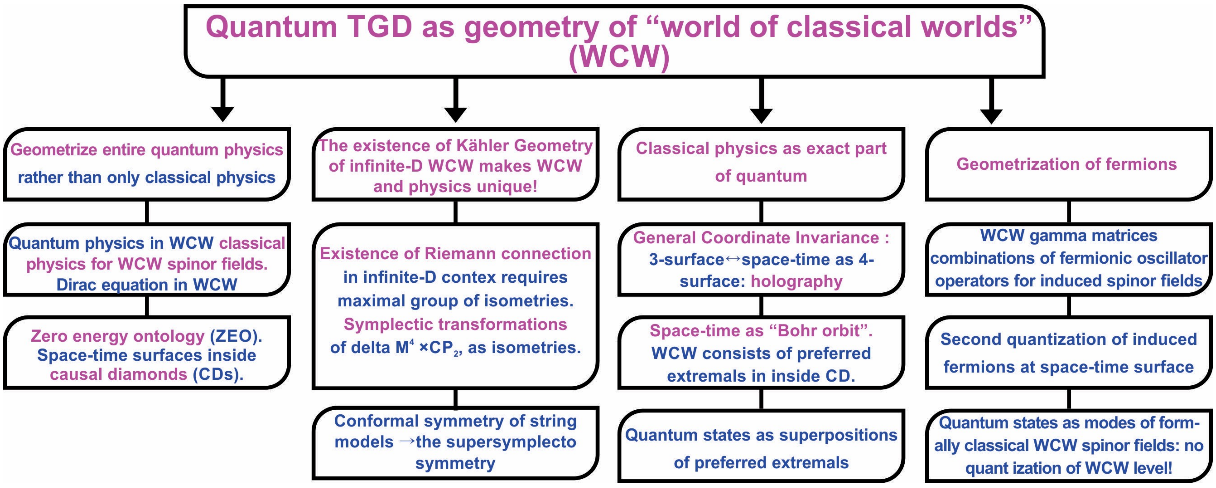


Figure 3: Geometrization of quantum physics in terms of WCW

The associated notion of causal diamond (CD) is essential element and assigns to elementary particles new fundamental time scales which are macroscopic: for electron the time scale is .1 seconds, the fundamental biorhythm. An essentially new element is time-like entanglement which allows to understand among other things the quantum counterparts of Boolean functions in terms of time-like entanglement in fermionic degrees of freedom.

- The assignment of dark matter with a hierarchy of Planck constants gives rise to a hierarchy of macroscopic quantum phases making possible macroscopic and macrotemporal quantum coherence and allowing to understand evolution as a gradual increase of Planck constant. The model for dark nucleons leads to a surprising conclusion: the states of nucleons correspond to DNA, RNA, tRNA, and amino-acids in a natural manner and vertebrate genetic code as correspondence between DNA and amino-acids emerges naturally. This suggests that genetic code is realized at the level of dark hadron physics and living matter in the usual sense provides a secondary representation for it. The hierarchy of Planck constants emerges from basic TGD under rather general assumptions.

- p-Adic physics can be identified as physics of cognition and intentionality. Negentropic entanglement possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds. NMP respects negentropic entanglement and the attractive idea is that the experience of understanding and positively colored emotions relate to negentropic entanglement.

- Living matter as conscious hologram is one of the basic ideas of TGD inspired biology and consciousness theory. The basic objection against TGD is that the interference of classical

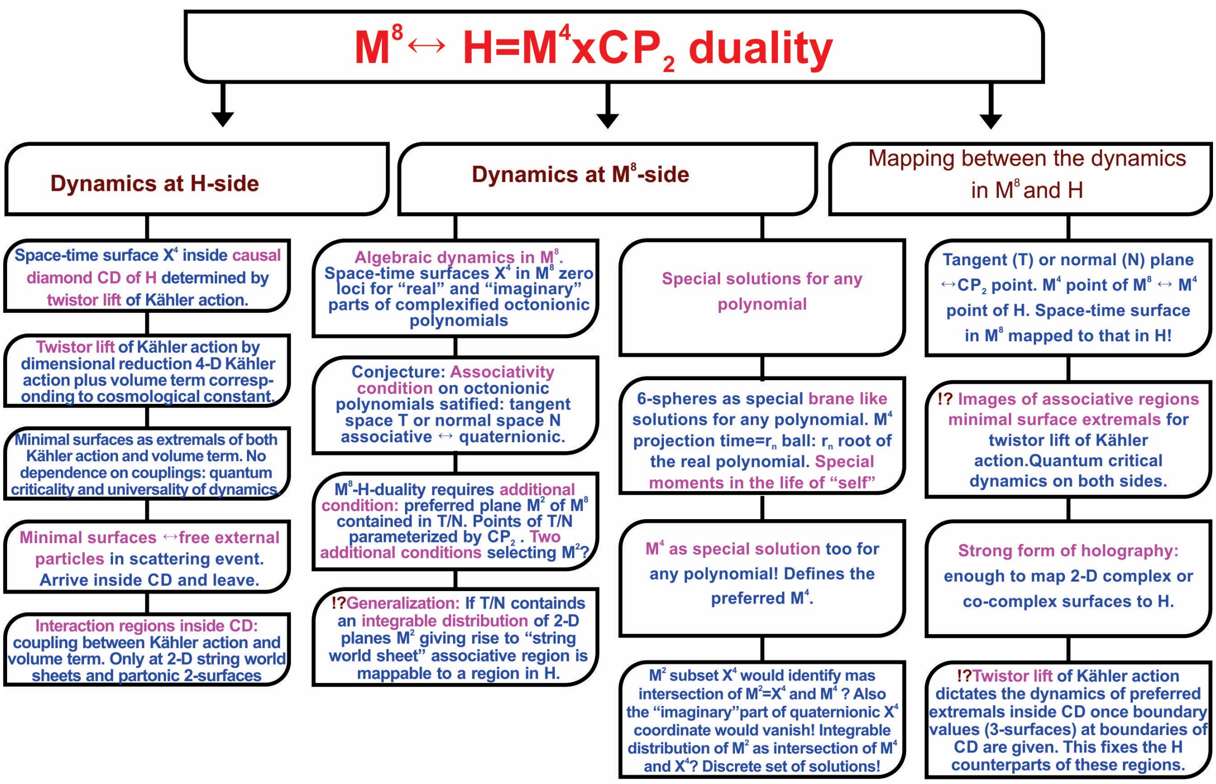


Figure 4: $M^8 - H$ duality

fields is impossible in the standard sense for the reason that that classical fields are not primary dynamical variables in TGD Universe. The resolution is based on the observation that only the interference of the effects caused by these fields can be observed experimentally and that many-sheeted space-time allows to realized the summation of effects in terms of multiple topological condensations of particles to several parallel space-time sheets. One concrete implication is fractality of qualia. Qualia appear in very wide range of scales: our qualia could in fact be those of magnetic body. The proposed mechanism for the generation of qualia realizes the fractality idea.

Various anomalies of living matter have been in vital role in the development of not only TGD view about living matter but also TGD itself.

- TGD approach to living matter was strongly motivated by the findings about the strange behavior of cell membrane and of cellular water, and gel behavior of cytoplasm. Also the findings about effects of ELF em fields on vertebrate brain were decisive and led to the proposal of the hierarchy of Planck constants found later to emerge naturally from the non-determinism of Kähler action. Rather satisfactorily, the other manner to introduce the hierarchy of Planck constants is in terms of gravitational Planck constant: at least in microscopic scales the equivalence of these approaches makes sense and leads to highly non-trivial predictions. The basic testable prediction is that dark photons have cyclotron frequencies inversely proportional to their masses but universal energy spectrum in visible and UV range which corresponds to the transition energies for biomolecules so that they are ideal for biocontrol at the level of both magnetic bodies and at the level of biochemistry.
- Water is in key role in living matter and also in TGD inspired view about living matter. The

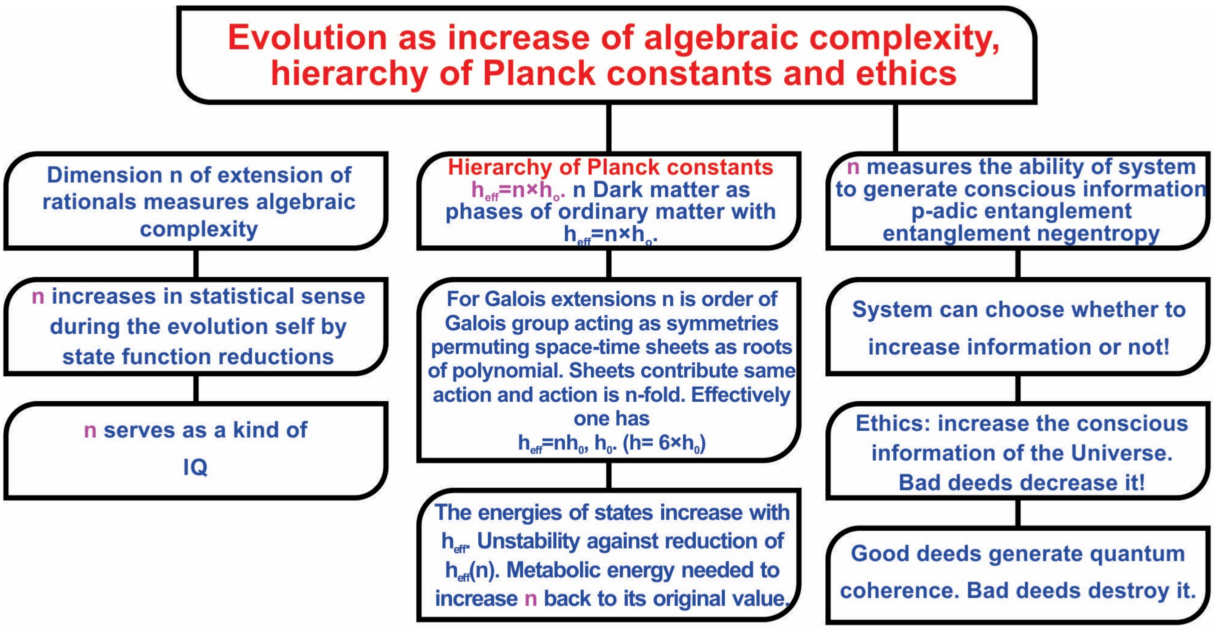


Figure 5: Number theoretic view of evolution

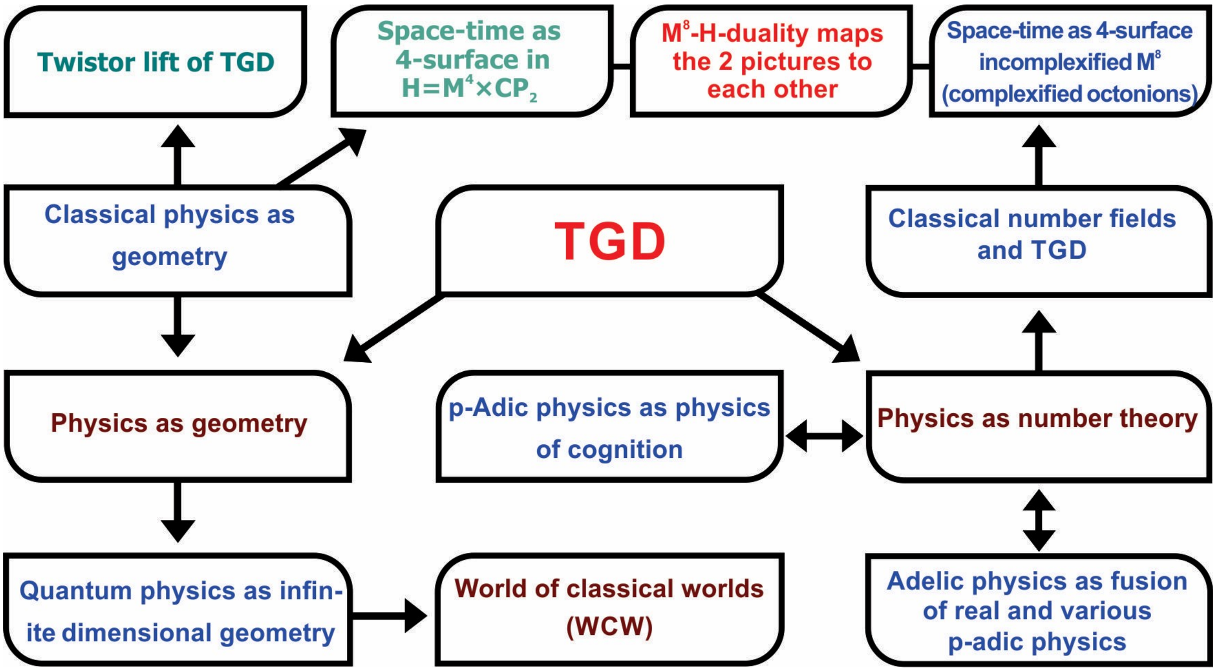


Figure 6: TGD is based on two complementary visions: physics as geometry and physics as number theory.

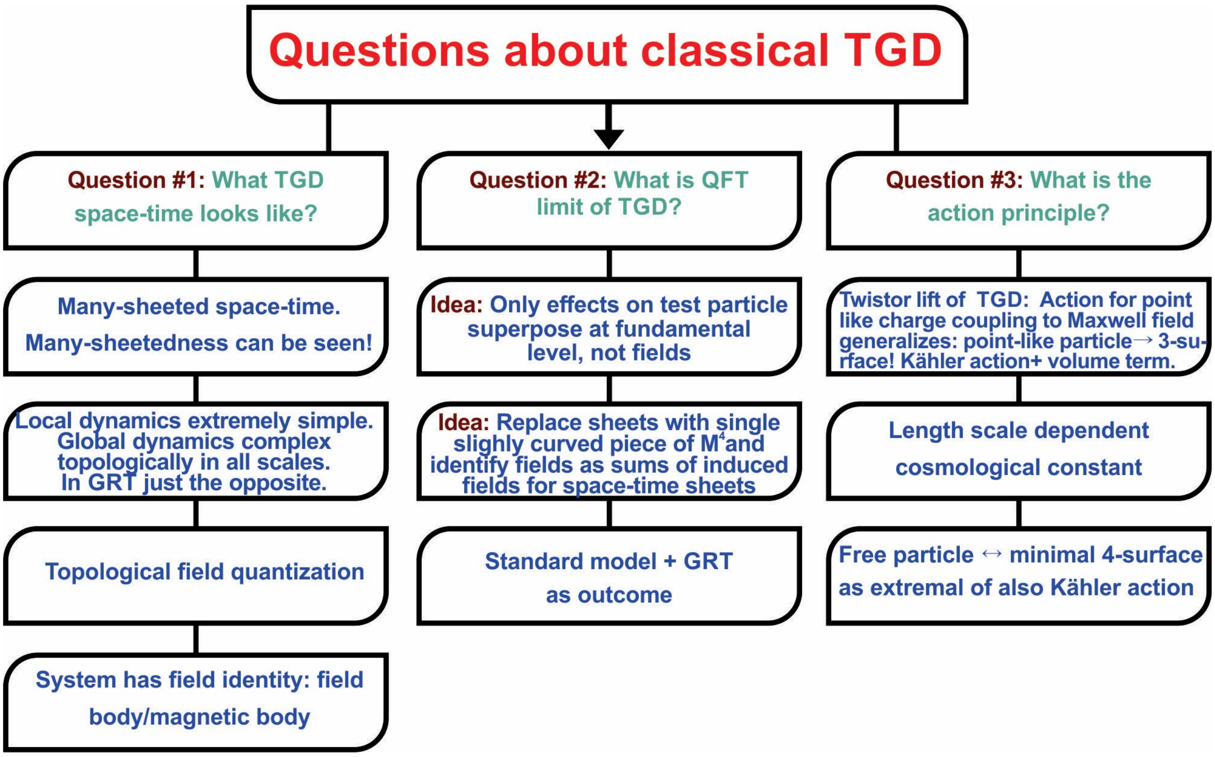


Figure 7: Questions about classical TGD.

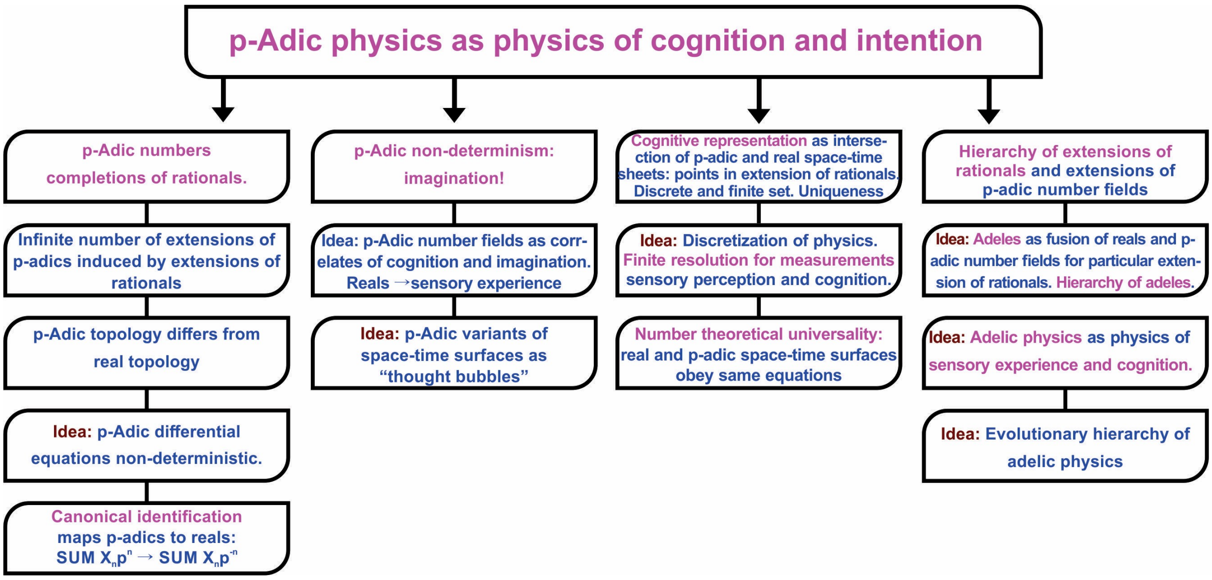


Figure 8: p-Adic physics as physics of cognition and imagination.

anomalies of water lead to a model for dark nuclei as dark proton strings with the surprising prediction that DNA, RNA, aninoacids and even tRNA are in one-one correspondence with the resulting 3-quark states and that vertebrate genetic code emerges naturally. This leads to a vision about water as primordial lifeform still playing a vital role in living organisms. The model of water memory and homeopathy in turn generalizes to a vision about how immune system might have evolved.

- Metabolic energy is necessary for conscious information processing in living matter. This suggests that metabolism should be basically tranfer of negentropic entanglement from nutrients to the organism. ATP could be seen as a molecule of consciousness in this picture and high energy phosphate bond would make possible the transfer of negentropy.

- Pollack effect and its generalizations are in a central role in the TGD inspire quantum biology. In the Pollack effect, the feed of energy allows to increase the value of effective Planck constant so that an ordinary charged particle transforms to its dark variant, being kicked to, say, the gravitational magnetic body of the system itself or some other system such as the Earth or Sun. Charge separation takes place between ordinary biomatter and its magnetic body. Dissipation is extremely small at the magnetic /field body so that Pollack effect makes it possible to realize various biological functions at the magnetic/field body. Photons, in particular solar photons, can provide the energy needed to increase the value of h_{eff} but there are many other possibilities. For instance, the formation of molecular bound states of atoms liberates energy which can be used in the Pollack effect and this process could generate dark matter at the magnetic and more general field bodies.

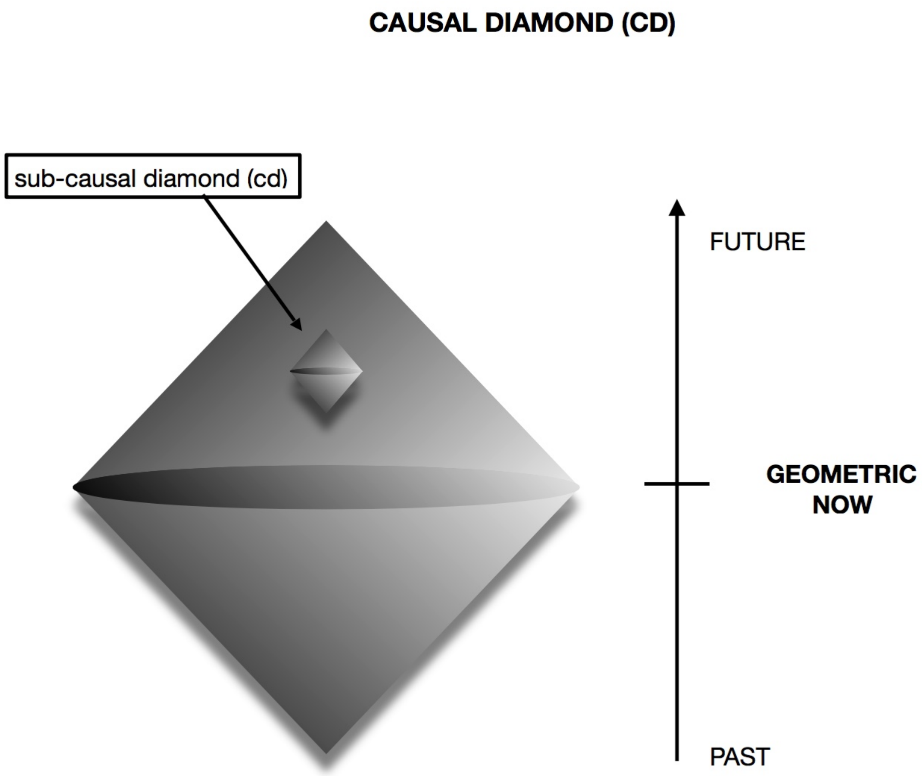


Figure 9: Causal diamond

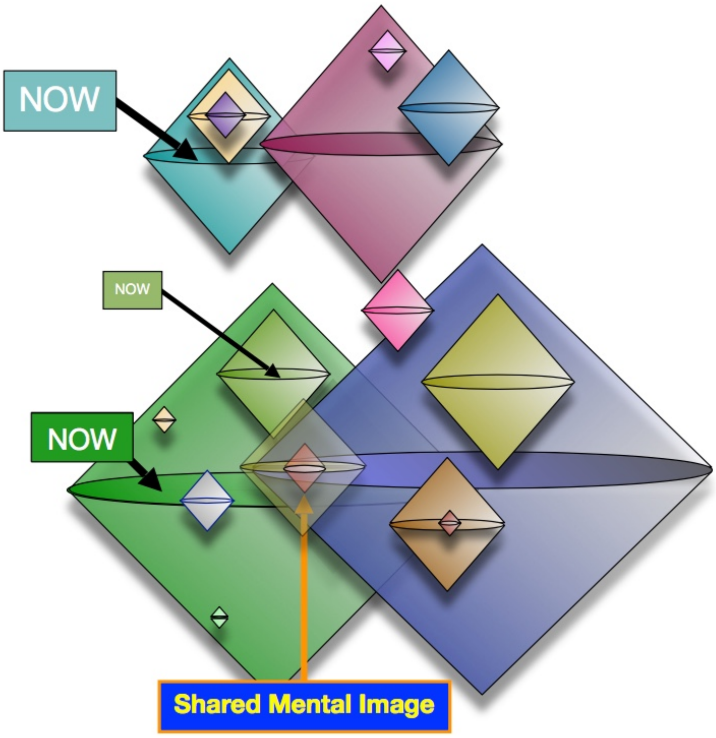


Figure 10: CDs define a fractal “conscious atlas”

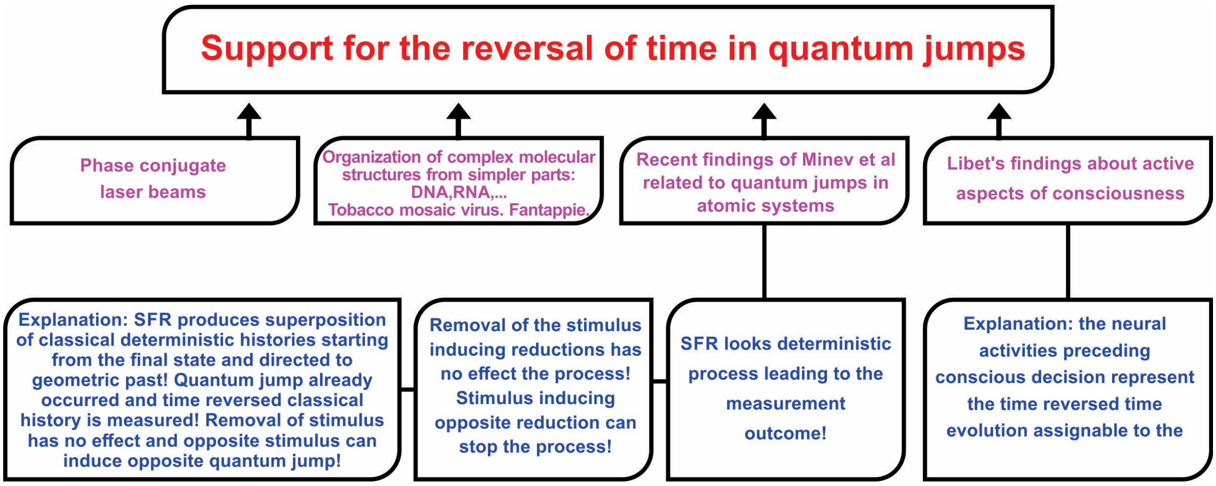


Figure 11: Time reversal occurs in BSFR

Figures

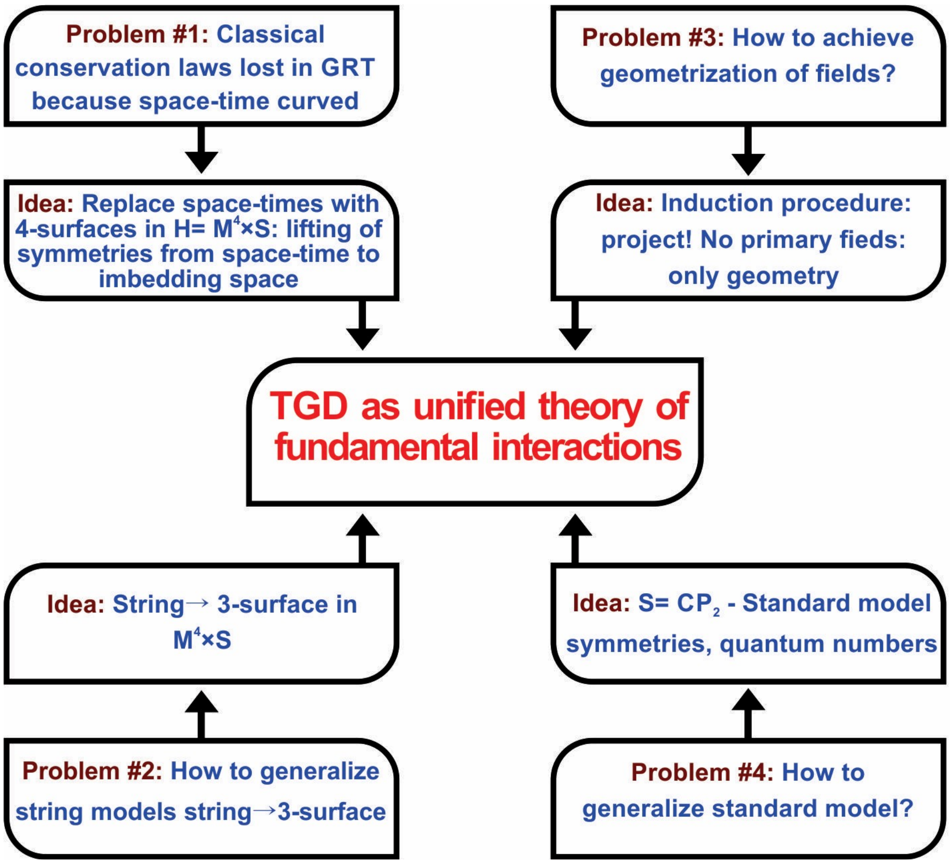
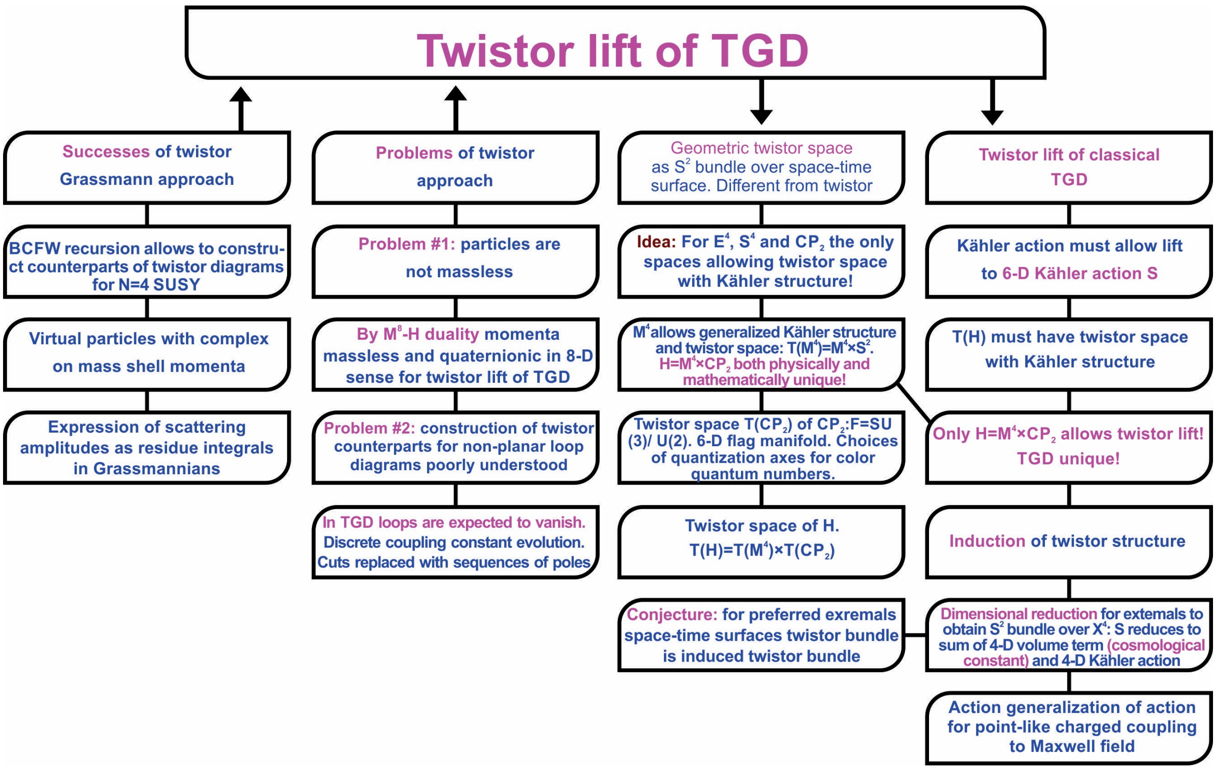


Figure 12: The problems leading to TGD as their solution.

What I have said above is strongly biased view about the recent situation in quantum TGD. This vision is single man's view and doomed to contain unrealistic elements as I know from experience. My dream is that young critical readers could take this vision seriously enough to try to demonstrate that some of its basic premises are wrong or to develop an alternative based on these or better premises. I must be however honest and tell that 45 years of TGD is a really vast bundle of thoughts and quite a challenge for anyone who is not able to cheat himself by taking the attitude of a blind believer or a light-hearted debunker trusting on the power of easy rhetoric tricks.

Karkkila, April 22, 2024, Finland

Matti Pitkänen



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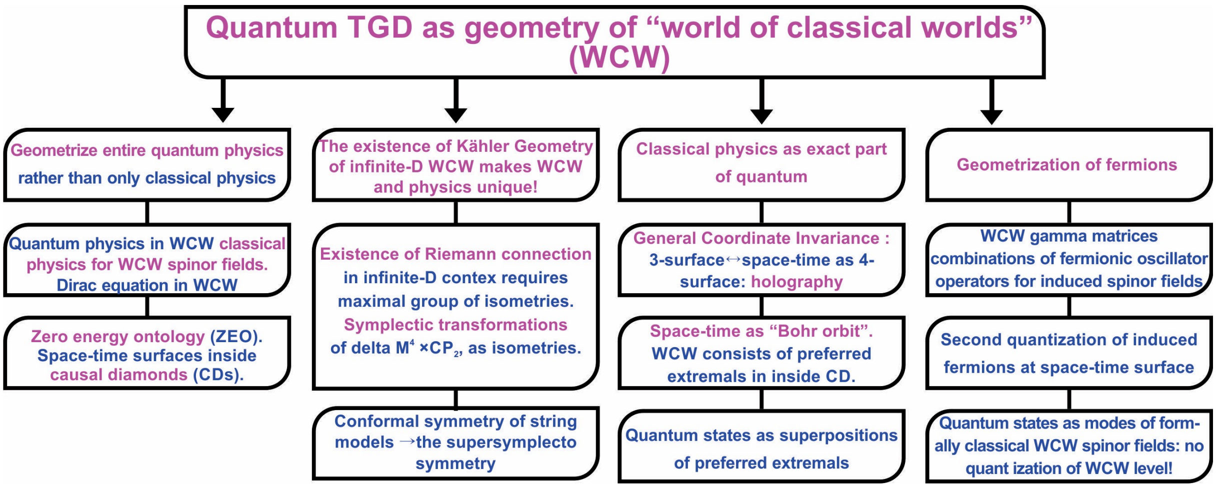


Figure 14: Geometrization of quantum physics in terms of WCW

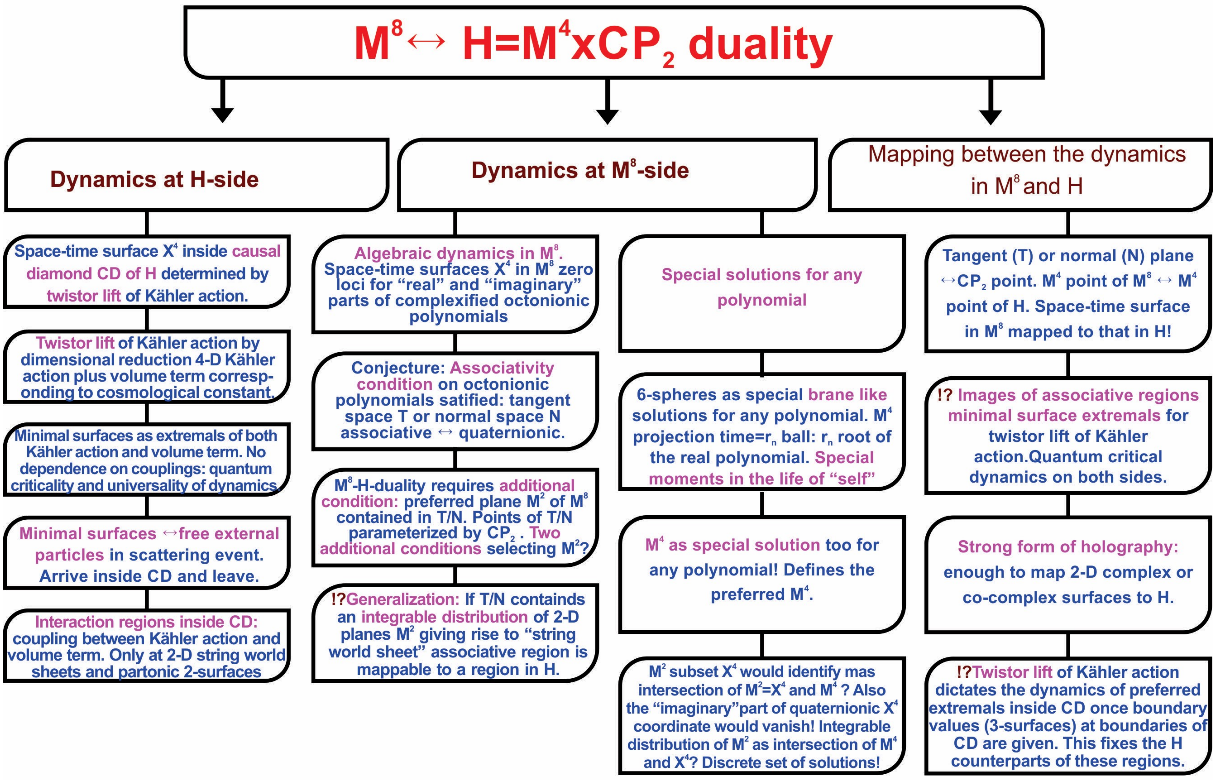


Figure 15: $M^8 - H$ duality

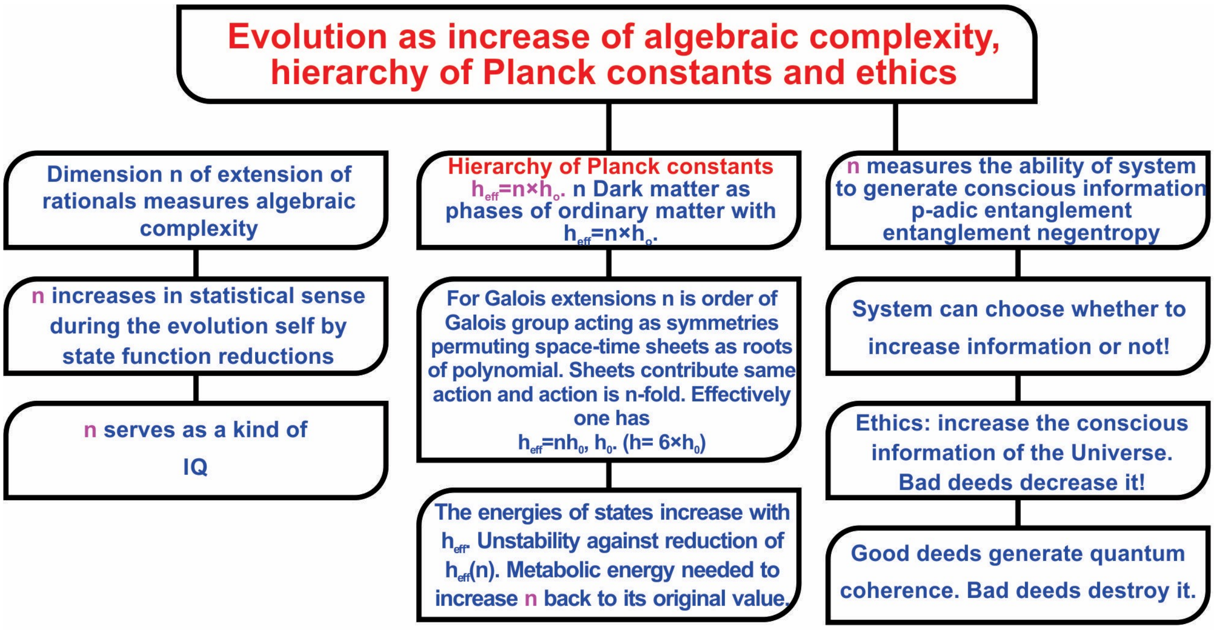


Figure 16: Number theoretic view of evolution

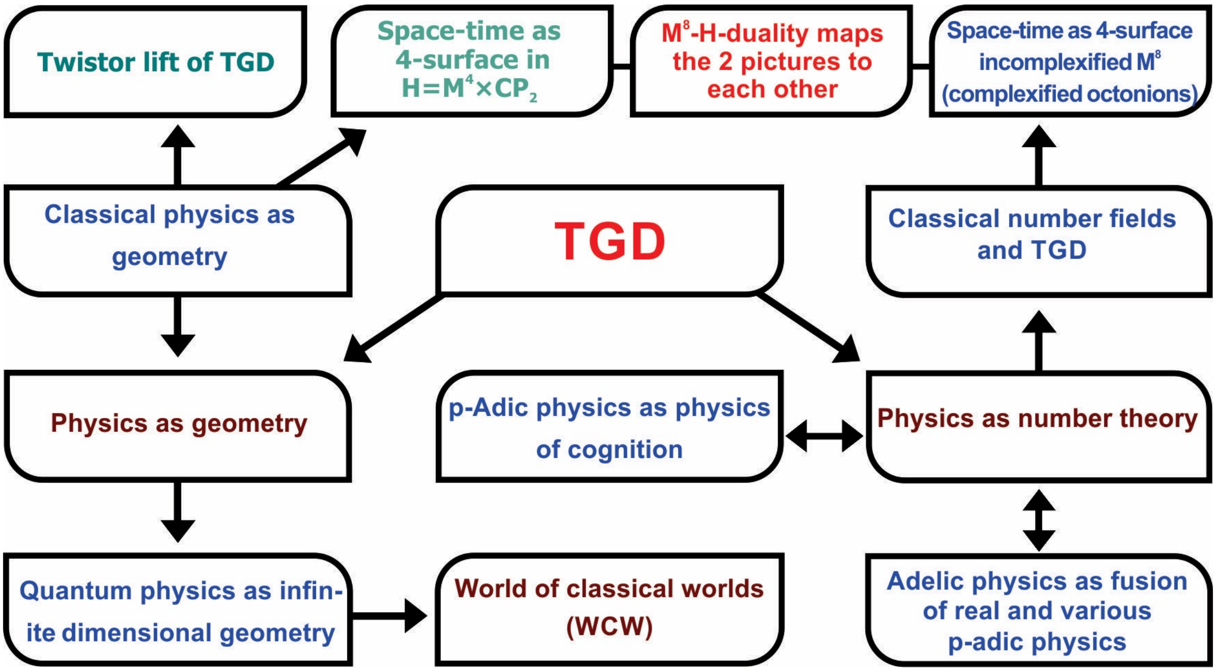


Figure 17: TGD is based on two complementary visions: physics as geometry and physics as number theory.

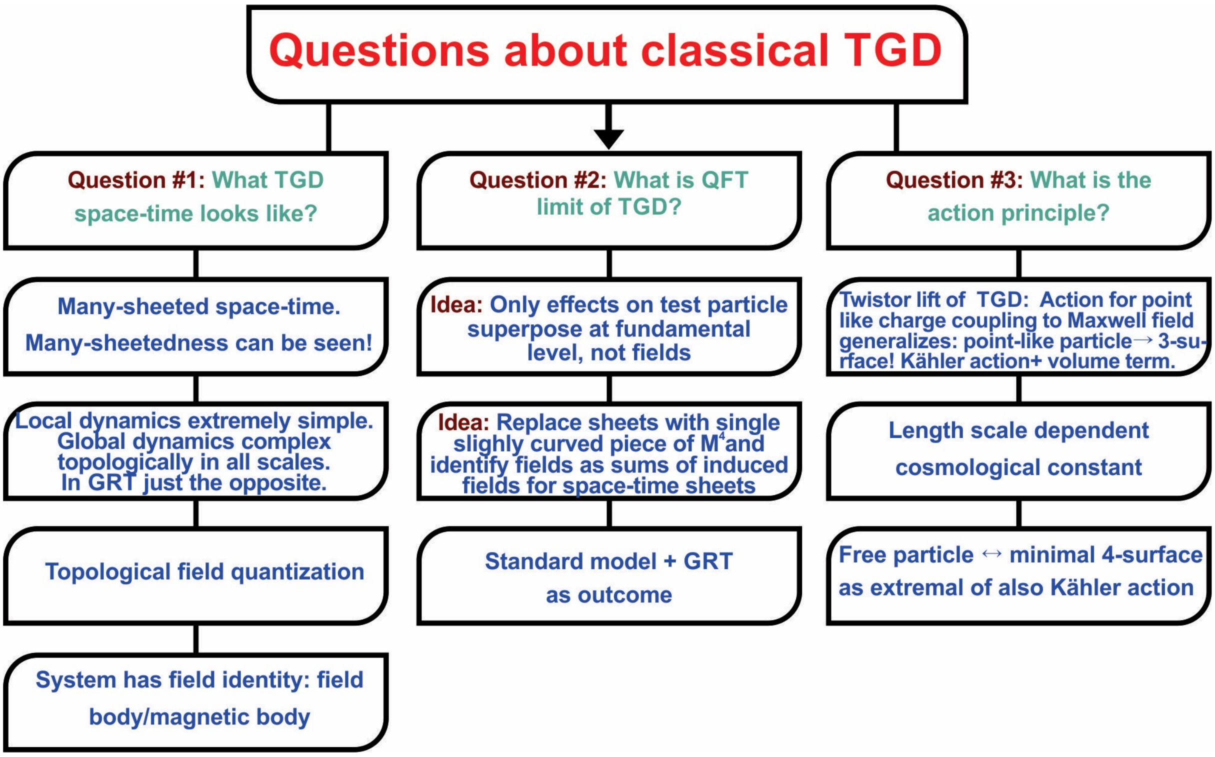


Figure 18: Questions about classical TGD.

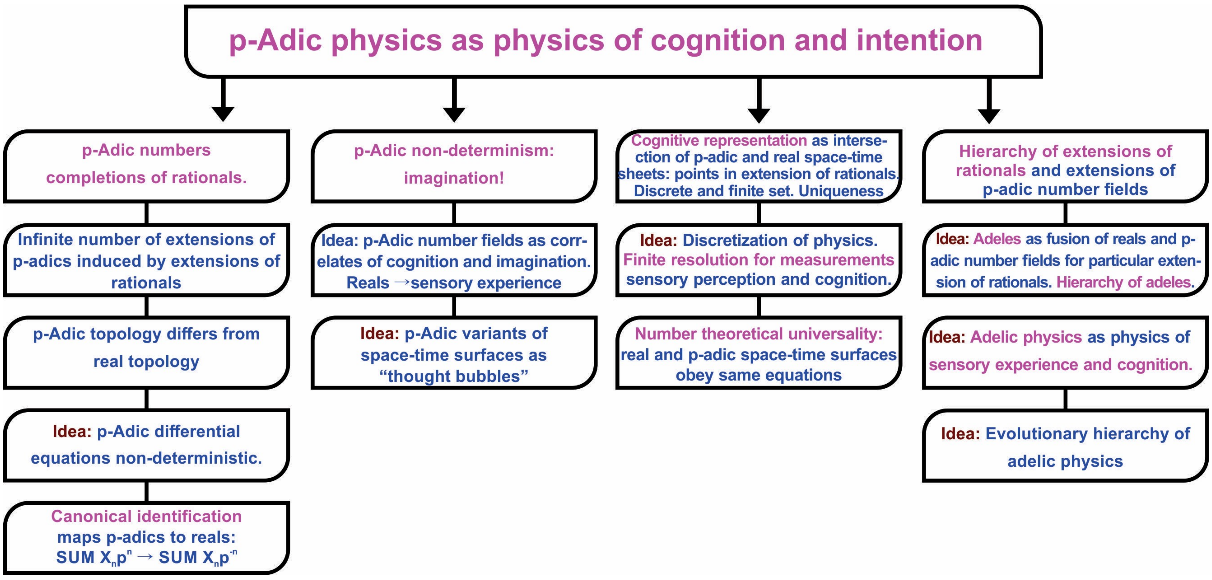


Figure 19: p-Adic physics as physics of cognition and imagination.

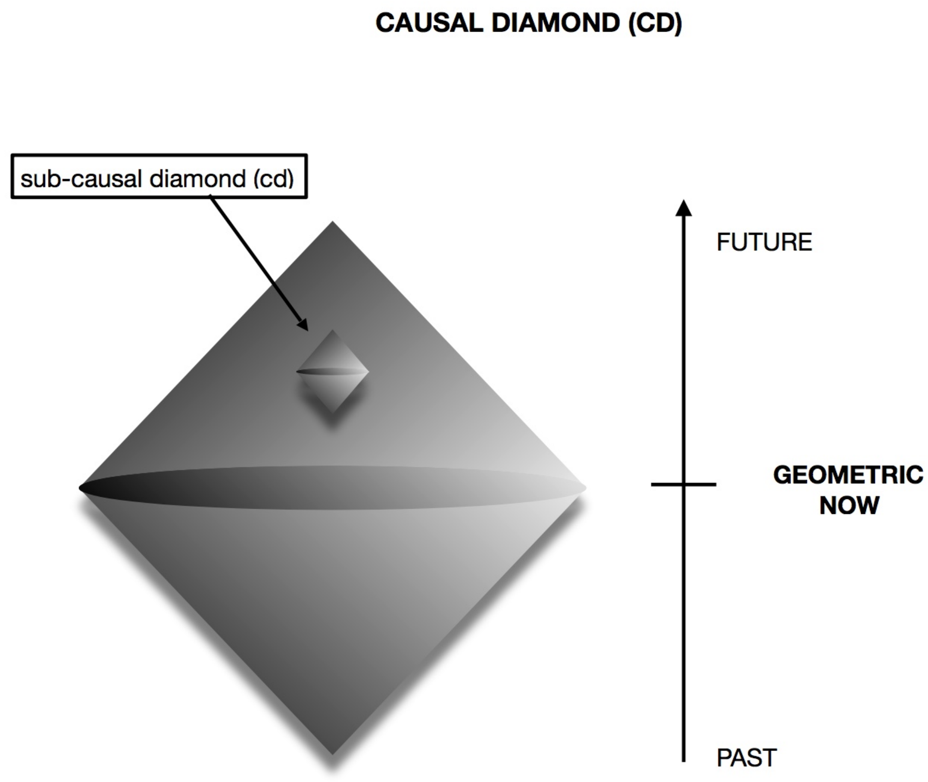
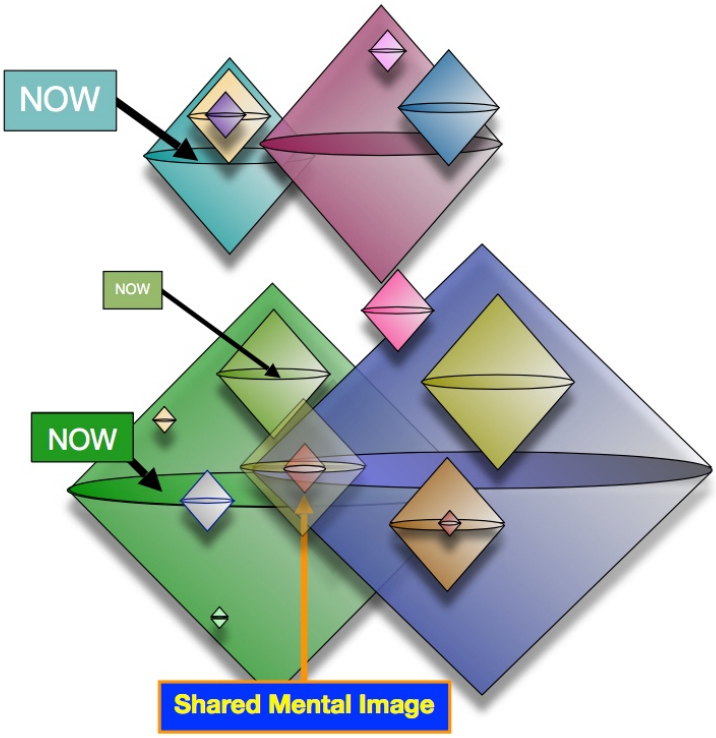


Figure 20: Causal diamond



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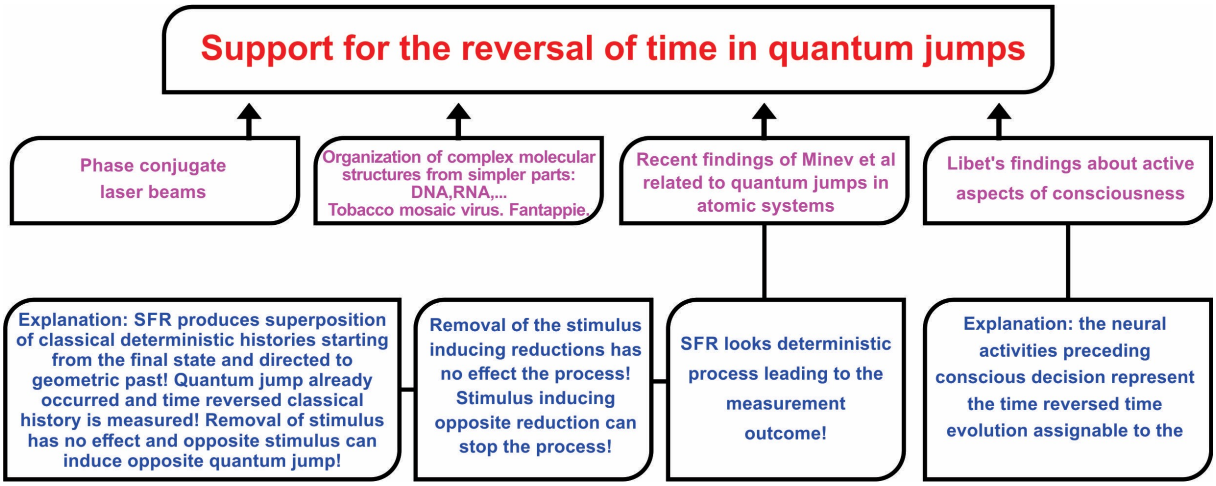

Figure 22: Time reversal occurs in BSFR

ACKNOWLEDGEMENTS

Neither TGD nor these books would exist without the help and encouragement of many people. The friendship with Heikki and Raija Haila and their family and Kalevi and Ritva Tikkanen and their family have been kept me in contact with the everyday world and without this friendship I would not have survived through these lonely 45 lonely years most of which I have remained unemployed as a scientific dissident. I am happy that my children have understood my difficult position and like my friends have believed that what I am doing is something valuable although I have not received any official recognition for it.

During the last decade Tapio Tammi has helped me quite concretely by providing the necessary computer facilities and being one of the few persons in Finland with whom to discuss my work. Pertti Kärkkäinen is my old physicist friend and has provided continued economic support for a long time. I have also had stimulating discussions with Samuli Penttinen who has also helped to get through the economical situations in which there seemed to be no hope. The continual updating of fifteen online books means quite a heavy bureaucracy at the level of bits and without a systemization one ends up with endless copying and pasting and internal consistency is soon lost. Tommi Ullgren has provided both economic support and encouragement during years. Pekka Rapinoja has offered his help in this respect and I am especially grateful to him for my Python skills.

During the last five years I have had inspiring discussions with many people in Finland interested in TGD. We have had video discussions with Sini Kunnas and had podcast discussions with Marko Manninen related to the TGD based view of physics and consciousness. Marko has also helped in the practical issues related to computers and quite recently he has done a lot of testing of chatGPT helping me to get an overall view of what it is. The discussions in a Zoom group involving Marko Manninen, Tuomas Sorakivi and Rode Majakka have given me the valuable opportunity to clarify my thoughts.

The collaboration with Lian Sidorov was extremely fruitful and she also helped me to survive economically through the hardest years. The participation in CASYS conferences in Liege has been an important window to the academic world and I am grateful for Daniel Dubois and Peter Marcer for making this participation possible. The discussions and collaboration with Eduardo de Luna and Istvan Dienes stimulated the hope that the communication of new vision might not be a mission impossible after all. Also blog discussions have been very useful. During these years I have received innumerable email contacts from people around the world. I am grateful to Mark McWilliams, Paul Kirsch, Gary Ehlenberg, and Ulla Matfolk and many others for providing links to possibly interesting websites and articles. We have collaborated with Peter Gariaev and Reza Rastmanesh. These contacts have helped me to avoid the depressive feeling of being some kind of Don Quixote of Science and helped me to widen my views: I am grateful for all these people.

In the situation in which the conventional scientific communication channels are strictly closed it is important to have some loop hole through which the information about the work done can at least in principle leak to the public through the iron wall of academic censorship. Without any exaggeration I can say that without the world wide web I would not have survived as a scientist nor as an individual. Homepage and blog are however not enough since only the formally published result is a result in recent day science. Publishing is however impossible without direct support from power holders- even in archives like arXiv.org.

Situation changed as Andrew Adamatsky proposed the writing of a book about TGD when I had already gotten used to the thought that my work would not be published during my lifetime. The Prespacetime Journal and two other journals related to quantum biology and consciousness - all of them founded by Huping Hu - have provided this kind of loophole. In particular, Dainis Zeps, Phil Gibbs, and Arkadiusz Jadczyk deserve my gratitude for their kind help in the preparation of an article series about TGD catalyzing a considerable progress in the understanding of quantum TGD. Also the viXra archive founded by Phil Gibbs and its predecessor Archive Freedom have been of great help: Victor Christianto deserves special thanks for doing the hard work needed to run Archive Freedom. Also the Neuroquantology Journal founded by Sultan Tarlaci deserves a special mention for its publication policy.

And last but not least: there are people who experience as a fascinating intellectual challenge to spoil the practical working conditions of a person working with something which might be called unified theory: I am grateful for the people who have helped me to survive through the virus attacks, an activity which has taken roughly one month per year during the last half decade and given a strong hue of grey to my hair.

For a person approaching his 73th birthday it is somewhat easier to overcome the hard feelings due to the loss of academic human rights than for an inpatient youngster. Unfortunately the economic situation has become increasingly difficult during the twenty years after the economic depression in Finland which in practice meant that Finland ceased to be a constitutional state in the strong sense of the word. It became possible to depose people like me from society without fear about public reactions and the classification as dropout became a convenient tool of ridicule to circumvent the ethical issues. During the period when the right wing held political power this trend was steadily strengthening and the situation is the same as I am writing this. In this kind of situation the concrete help from individuals has been and will be of utmost importance. Against this background it becomes obvious that this kind of work is not possible without the support from outside and I apologize for not being able to mention all the people who have helped me during these years.

Karkkila, August 30, 2023, Finland

Matti Pitkänen

Contents

List of Figures

Chapter 1

Introduction

1.1 Basic Ideas of Topological Geometrodynamics (TGD)

Standard model describes rather successfully both electroweak and strong interactions but sees them as totally separate and contains a large number of parameters which it is not able to predict. For about four decades ago unified theories known as Grand Unified Theories (GUTs) trying to understand electroweak interactions and strong interactions as aspects of the same fundamental gauge interaction assignable to a larger symmetry group emerged. Later superstring models trying to unify even gravitation and strong and weak interactions emerged. The shortcomings of both GUTs and superstring models are now well-known. If TGD - whose basic idea emerged towards the end of 1977 - would emerge now it would be seen as an attempt to solve the difficulties of these approaches to unification.

The basic physical picture behind the geometric vision of TGD corresponds to a fusion of two rather disparate approaches: namely TGD as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model. After 1995 number theoretic vision started to develop and was initiated by the success of mass calculations based on p-adic thermodynamics. Number theoretic vision involves all number fields and is complementary to the geometric vision: one can say that this duality is analogous to momentum-position duality of wave mechanics. TGD can be also regarded as topological quantum theory in a very general sense as already the attribute "Topological" in "TGD" makes clear. Space-time surfaces as minimal surfaces can be regarded as representatives of homology equivalence classes and p-adic topologies generalize the notion of local topology and apply to the description of correlates of cognition.

1.1.1 Geometric Vision Very Briefly

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [K2].

The basic vision and its relationship to existing theories is now rather well understood.

1. Space-times are representable as 4-surfaces in the 8-dimensional embedding space $H = M^4 \times CP_2$, where M^4 is 4-dimensional (4-D) Minkowski space and CP_2 is 4-D complex projective space (see Appendix).

2. Induction procedure (a standard procedure in fiber bundle theory, see Appendix) allows to geometrize various fields. Space-time metric characterizing gravitational fields corresponds to the induced metric obtained by projecting the metric tensor of H to the space-time surface. Electroweak gauge potentials are identified as projections of the components of CP_2 spinor connection to the space-time surface, and color gauge potentials as projections of CP_2 Killing vector fields representing color symmetries. Also spinor structure can be induced: induced spinor gamma matrices are projections of gamma matrices of H and induced spinor fields just H spinor fields restricted to space-time surface. Spinor connection is also projected. The interpretation is that distances are measured in embedding space metric and parallel translation using spinor connection of embedding space.

Twistor lift of TGD means that one can lift space-time surfaces in H to 6-D surfaces a analogs of twistor space of space-time surface in the Cartesian product of the twistor spaces of M^4 and CP_2, which are the only 4-manifolds allowing twistor space with Kähler structure [A17]. The twistor structure would be induced in some sense, and should coincide with that associated with the induced metric. Clearly, the 2-spheres defining the fibers of twistor spaces of M^4 and CP_2 must allow identification: this 2-sphere defines the S^2 fiber of the twistor space of the space-time surface. This poses a constraint on the embedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces. The existence of Kähler structure allows to lift 4-D Kähler action to its 6-D counterparts and the 6-D counterpart of twistor space is obtained by its dimensional reduction so that one obtains a sphere bundle. This makes possible twistorialization for all space-time surfaces: in general relativity the general metric does not allow this.

3. A geometrization of quantum numbers is achieved. The isometry group of the geometry of CP_2 codes for the color gauge symmetries of strong interactions. Vierbein group codes for electroweak symmetries, and explains their breaking in terms of CP_2 geometry so that standard model gauge group results. There are also important deviations from the standard model: color quantum numbers are not spin-like but analogous to orbital angular momentum: this difference is expected to be seen only in CP_2 scale. In contrast to GUTs, quark and lepton numbers are separately conserved and family replication has a topological explanation in terms of topology of the partonic 2-surface carrying fermionic quantum numbers.

   M^4 and CP_2 are unique choices for many other reasons. For instance, they are the unique 4-D space-times allowing twistor space with Kähler structure. M^4 light-cone boundary allows a huge extension of 2-D conformal symmetries. M^4 and CP_2 allow quaternionic structures. Therefore standard model symmetries have number theoretic meaning.

4. Induced gauge potentials are expressible in terms of embedding space coordinates and their gradients and general coordinate invariance implies that there are only 4 field-like variables locally. Situation is thus extremely simple mathematically. The objection is that one loses linear superposition of fields. The resolution of the problem comes from the generalization of the concepts of particle and space-time.

   Space-time surfaces can be also particle like having thus finite size. In particular, space-time regions with Euclidian signature of the induced metric (temporal and spatial dimensions in the same role) emerge and have interpretation as lines of generalized Feynman diagrams. Particles in space-time can be identified as a topological inhomogeneities in background space-time surface which looks like the space-time of general relativity in long length scales.

   One ends up with a generalization of space-time surface to many-sheeted space-time with space-time sheets having extremely small distances of about 10^4 Planck lengths (CP_2 size). As one adds a particle to this kind of structure, it touches various space-time sheets and thus interacts with the associated classical fields. Their effects superpose linearly in good approximation and linear superposition of fields is replaced with that for their effects.

   This resolves the basic objection. It also leads to the understanding of how the space-time of general relativity and quantum field theories emerges from TGD space-time as effective space-time when the sheets of many-sheeted space-time are lumped together to form a region of Minkowski space with metric replaced with a metric identified as the sum of empty Minkowski metric and deviations of the metrics of sheets from empty Minkowski metric. Gauge potentials are identified as sums of the induced gauge potentials. TGD is therefore a microscopic theory from which the standard model and general relativity follow as a topological simplification, however forcing a dramatic increase of the number of fundamental field variables.

5. A further objection is that classical weak fields identified as induced gauge fields are long ranged and should cause large parity breaking effects due to weak interactions. These effects are indeed observed but only in living matter. The basic problem is that one has long ranged classical electroweak gauge fields. The resolution of the problem is that the quantum averages of induced weak and color gauge fields vanish due to the fact that color rotations affect both space-time surfaces and induced weak and color fields. Only the averages of

electromagnetic fields are nonvanishing. The correlations functions for weak fields are non-vanishing below Compton lengths of weak bosons. In living matter large values of effective Planck constant labelling phases of ordinary matter identified as dark matter make possible long ranged weak fields and color fields.

6. General coordinate invariance requires holography so that space-time surfaces are analogous to Bohr orbits for particles identified as 3-surfaces. Bohr orbit property would be naturally realized by a 4-D generalization of holomorphy of string world sheets and implies that the space-time surfaces are minimal surfaces apart from singularities. This holds true for any action as long as it is general coordinate invariant and constructible in terms of the induced geometry. String world sheets and light-like orbits of partonic 2-surfaces correspond to singularities at which the minimal surface property of the space-time surfaces realizing the preferred extremal property fails. Preferred extremals are not completely deterministic, which implies what I call zero energy ontology (ZEO) meaning that the Bohr orbits are the fundamental objects. This leads to a solution of the basic paradox of quantum measurement theory. Also the mathematically ill-defined path integral disappears and leaves only the well-defined functional integral over the Bohr orbits.

7. A string model-like picture emerges from TGD and one ends up with a rather concrete view about the topological counterpart of Feynman diagrammatics. The natural stringy action would be given by the string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant could be present as a fundamental constant in string action and the ratio $\hbar/G/R^2$ would be determined by quantum criticality conditions. The hierarchy of Planck constants $h_{eff}/h = n$ assigned to dark matter in TGD framework would allow to circumvent the objection that only objects of length of order Planck length are possible since string tension given by $T = 1/\hbar_{eff}G$ apart from numerical factor could be arbitrary small. This would make possible gravitational bound states as partonic 2-surfaces as structures connected by strings and solve the basic problem of superstring theories. This option allows the natural interpretation of M^4 type vacuum extremals with CP_2 projection, which is Lagrange manifold as good approximations for space-time sheets at macroscopic length scales. String area does not contribute to the Kähler function at all.

   Whether induced spinor fields associated with Kähler-Dirac action and de-localized inside the entire space-time surface should be allowed remains an open question: super-conformal symmetry strongly suggests their presence. A possible interpretation for the corresponding spinor modes could be in terms of dark matter, sparticles, and hierarchy of Planck constants.

It is perhaps useful to make clear what TGD is not and also what new TGD can give to physics.

1. TGD is *not* just General Relativity made concrete by using embeddings: the 4-surface property is absolutely essential for unifying standard model physics with gravitation and to circumvent the incurable conceptual problems of General Relativity. The many-sheeted space-time of TGD gives rise only at the macroscopic limit to GRT space-time as a slightly curved Minkowski space. TGD is *not* a Kaluza-Klein theory although color gauge potentials are analogous to gauge potentials in these theories.

   TGD space-time is 4-D and its dimension is due to completely unique conformal properties of light-cone boundary and 3-D light-like surfaces implying enormous extension of the ordinary conformal symmetries. Light-like 3-surfaces represent orbits of partonic 2-surfaces and carry fundamental fermions at 1-D boundaries of string world sheets. TGD is *not* obtained by performing Poincare gauging of space-time to introduce gravitation and is plagued by profound conceptual problems.

2. TGD is *not* a particular string model although string world sheets emerge in TGD very naturally as loci for spinor modes: their 2-dimensionality makes among other things possible quantum deformation of quantization known to be physically realized in condensed matter, and conjectured in TGD framework to be crucial for understanding the notion of finite measurement resolution. Hierarchy of objects of dimension up to 4 emerge from TGD: this obviously means analogy with branes of super-string models.

TGD is *not* one more item in the collection of string models of quantum gravitation relying on Planck length mystics. Dark matter becomes an essential element of quantum gravitation and quantum coherence in astrophysical scales is predicted just from the assumption that strings connecting partonic 2-surfaces are responsible for gravitational bound states.

TGD is *not* a particular string model although AdS/CFT duality of super-string models generalizes due to the huge extension of conformal symmetries and by the identification of WCW gamma matrices as Noether super-charges of super-symplectic algebra having a natural conformal structure.

3. TGD is *not* a gauge theory. In TGD framework the counterparts of also ordinary gauge symmetries are assigned to super-symplectic algebra (and its Yangian [A4] [B20, B16, B17]), which is a generalization of Kac-Moody algebras rather than gauge algebra and suffers a fractal hierarchy of symmetry breakings defining hierarchy of criticalities. TGD is *not* one more quantum field theory like structure based on path integral formalism: path integral is replaced with functional integral over 3-surfaces, and the notion of classical space-time becomes an exact part of the theory. Quantum theory becomes formally a purely classical theory of WCW spinor fields: only state function reduction is something genuinely quantal.

4. TGD view about spinor fields is *not* the standard one. Spinor fields appear at three levels. Spinor modes of the embedding space are analogs of spinor modes characterizing incoming and outgoing states in quantum field theories. Induced second quantized spinor fields at space-time level are analogs of stringy spinor fields. Their modes are localized by the well-definedness of electro-magnetic charge and by number theoretic arguments at string world sheets. Kähler-Dirac action is fixed by supersymmetry implying that ordinary gamma matrices are replaced by what I call Kähler-Dirac gamma matrices - this something new. WCW spinor fields, which are classical in the sense that they are not second quantized, serve as analogs of fields of string field theory and imply a geometrization of quantum theory.

5. TGD is in some sense an extremely conservative geometrization of entire quantum physics: *no* additional structures such as gauge fields as independent dynamical degrees of freedom are introduced: Kähler geometry and associated spinor structure are enough. "Topological" in TGD should not be understood as an attempt to reduce physics to torsion (see for instance [B13]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of the everyday world represent non-trivial topology of space-time in the TGD Universe.

6. Twistor space - or rather, a generalization of twistor approach replacing masslessness in 4-D sense with masslessness in 8-D sense and thus allowing description of also massive particles - emerged originally as a technical tool, and its Kähler structure is possible only for $H = M^4 \times CP_2$. It however turned out that much more than a technical tool is in question. What is genuinely new is the infinite-dimensional character of the Kähler geometry making it highly unique, and its generalization to p-adic number fields to describe correlates of cognition. Also the hierarchy of Planck constants $h_{eff} = n \times h$ reduces to the quantum criticality of the TGD Universe and p-adic length scales and Zero Energy Ontology represent something genuinely new.

The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last 45 years to the realization of this dream and this has resulted in 26 online books about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology.

A collection of 30 online books is now (August 2023) under preparation. The goal is to minimize overlap between the topics of the books and make the focus of a given book sharper.

1.1.2 Two Visions About TGD as Geometrization of Physics and Their Fusion

As already mentioned, TGD as a geometrization of physics can be interpreted both as a modification of general relativity and generalization of string models.

TGD as a Poincare Invariant Theory of Gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_\times CP_2$, where M^4 denotes Minkowski space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [A12, A16, A7, A14].

The identification of the space-time as a sub-manifold [A13, A20] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity.

It soon however turned out that sub-manifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

The choice of H is unique from the condition that TGD has standard model symmetries. Also number theoretical vision selects $H = M^4 \times CP_2$ uniquely. M^4 and CP_2 are also unique spaces allowing twistor space with Kähler structure.

TGD as a Generalization of the Hadronic String Model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

This decay vertex does not however correspond to a direct generalization of trouser vertex of string models. Indeed, the important difference between TGD and string models is that the analogs of string world sheet diagrams do not describe particle decays but the propagation of particles via different routes. Particle reactions are described by generalized Feynman diagrams for which 3-D light-like surface describing particle propagating join along their ends at vertices. As 4-manifolds the space-time surfaces are therefore singular like Feynman diagrams as 1-manifolds.

Quite recently, it has turned out that fermionic strings inside space-time surfaces define an exact part of quantum TGD and that this is essential for understanding gravitation in long length scales. Also the analog of AdS/CFT duality emerges in that the Kähler metric can be defined either in terms of Kähler function identifiable as Kähler action assignable to Euclidian space-time regions or Kähler action + string action assignable to Minkowskian regions.

The recent view about construction of scattering amplitudes is very "stringy". By strong form of holography string world sheets and partonic 2-surfaces provide the data needed to construct scattering amplitudes. Space-time surfaces are however needed to realize quantum-classical correspondence necessary to understand the classical correlates of quantum measurement. There is a huge generalization of the duality symmetry of hadronic string models.

The proposal is that scattering amplitudes can be regarded as sequences of computational operations for the Yangian of super-symplectic algebra. Product and co-product define the basic vertices and realized geometrically as partonic 2-surfaces and algebraically as multiplication for the elements of Yangian identified as super-symplectic Noether charges assignable to strings. Any computational sequences connecting given collections of algebraic objects at the opposite boundaries of causal diamond (CD) produce identical scattering amplitudes.

Fusion of the Two Approaches via a Generalization of the Space-Time Concept

The problem is that the two approaches to TGD seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there could be "vapor phase" that is a "gas" of particle like 3-surfaces and string like objects (counterpart of the "baby universes" of GRT) and the non-conservation of energy in GRT corresponds to the transfer of energy between different sheets of the space-time and possible existence vapour phase.

. What one obtains is what I have christened as many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig. ??** in the appendix of this book). One particular aspect is topological field quantization meaning that various classical fields assignable to a physical system correspond to space-time sheets representing the classical fields to that particular system. One can speak of the field body of a particular physical system. Field body consists of topological light rays, and electric and magnetic flux quanta. In Maxwell's theory the physical system does not possess this kind of field identity. The notion of the magnetic body is one of the key players in TGD inspired theory of consciousness and quantum biology. The existence of monopole flux tubes requiring no current as a source of the magnetic field makes it possible to understand the existence of magnetic fields in cosmological and astrophysical scales.

This picture became more detailed with the advent of zero energy ontology (ZEO). The basic notion of ZEO is causal diamond (CD) identified as the Cartesian product of CP_2 and of the intersection of future and past directed light-cones and having scale coming as an integer multiple of CP_2 size is fundamental. CDs form a fractal hierarchy and zero energy states decompose to products of positive and negative energy parts assignable to the opposite boundaries of CD defining the ends of the space-time surface. The counterpart of zero energy state in positive energy ontology is the pair of initial and final states of a physical event, say particle reaction.

At space-time level ZEO means that 3-surfaces are pairs of space-like 3-surfaces at the opposite light-like boundaries of CD. Since the extremals of Kähler action connect these, one can say that by holography the basic dynamical objects are the space-time surface connecting these 3-surfaces and identifiable as analogs of Bohr orbits. This changes totally the vision about notions like self-organization: self-organization by quantum jumps does not take for a 3-D system but for the entire 4-D field pattern associated with it.

General Coordinate Invariance (GCI) allows to identify the basic dynamical objects as space-like 3-surfaces at the ends of space-time surface at boundaries of CD: this means that space-time surface is analogous to Bohr orbit. An alternative identification of the lines of generalized Feynman diagrams is as light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian . Also the Euclidian 4-D regions can have a similar interpretation. The requirement that the two interpretations are equivalent, leads to a strong form of General Coordinate Invariance. The outcome is effective 2-dimensionality stating that the partonic 2-surfaces identified as intersections of the space-like ends of space-time surface and light-like wormhole throats are the fundamental objects. That only effective 2-dimensionality is in question is due to the effects caused by the failure of strict determinism of Kähler action. In finite length scale resolution these effects can be neglected below UV cutoff and above IR cutoff. One can also speak about a strong form of holography.

The understanding of the super symplectic invariance leads to the proposal that super symplectic algebra and other Kac-Moody type algebras labelled by non-negative multiples of basic conformal weights allow a hierarchy of symmetry breakings in which the analog of gauge symmetry breaks down to a genuine dynamical symmetry. This gives rise to fractal hierarchies of algebras and symmetry breakings. This breaking can occur also for ordinary conformal algebras if one restricts the conformal weights to be non-negative integers.

1.1.3 Basic Objections

Objections are the most powerful tool in theory building. The strongest objection against TGD is the observation that all classical gauge fields are expressible in terms of four embedding space coordinates only- essentially CP_2 coordinates. The linear superposition of classical gauge fields taking place independently for all gauge fields is lost. This would be a catastrophe without many-sheeted space-time. Instead of gauge fields, only the effects such as gauge forces are superposed. Particles topologically condense to several space-time sheets simultaneously and experience the sum of gauge forces. This transforms the weakness to extreme economy: in a typical unified theory the number of primary field variables is countered in hundreds if not thousands, now it is just four.

Second objection is that TGD space-time is quite too simple as compared to GRT space-time due to the embeddability to 8-D embedding space. One can also argue that Poincare invariant theory of gravitation cannot be consistent with General Relativity. The above interpretation makes it possible to understand the relationship to GRT space-time and how the Equivalence Principle (EP) follows from Poincare invariance of TGD. The interpretation of GRT space-time is as effective space-time obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrics of the space-time sheets from Minkowski metric. Poincare invariance strongly suggests classical EP for the GRT limit in long length scales at least. One can also consider other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with a very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of the standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

Topological Field Quantization

Topological field quantization distinguishes between TGD based and more standard - say Maxwellian - notion of field. In Maxwell's fields created by separate systems superpose and one cannot tell which part of field comes from which system except theoretically. In TGD these fields correspond to different space-time sheets and only their effects on test particle superpose. Hence physical systems have well-defined field identifies - field bodies - in particular magnetic bodies.

The notion of magnetic body carrying dark matter with non-standard large value of Planck constant has become central concept in TGD inspired theory of consciousness and living matter, and by starting from various anomalies of biology one ends up to a rather detailed view about the role of magnetic body as intentional agent receiving sensory input from the biological body and controlling it using EEG and its various scaled up variants as a communication tool. Among other thins this leads to models for cell membrane, nerve pulse, and EEG.

1.1.4 Quantum TGD as Spinor Geometry of World of Classical Worlds

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and have been the following ones.

World of Classical Worlds

The notion of WCW reduces the interacting quantum theory to a theory of free WCW spinor fields.

1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude identified as WCW spinor in the configuration space CH ("world of classical worlds", WCW) consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included.

2. 4-D general coordinate invariance forces holography and replaces the ill-defined path integral over all space-time surfaces with a discrete sum over 4-D analogs of Bohr orbits for particles identified as 3-surfaces. Holography means that basic objects are these analogs of Bohr orbits. Since there is no quantization at the level of WCW, one has an analog of wave mechanics with point-like particles replaced with 4-D Bohr orbits.

3. One must geometrize WCW as the space of Bohr orbits. In an infinite-dimensional situation the existence of geometry requires maximal symmetries already in the case of loop spaces. Physics is unique from its mathematical existence.

   WCW is endowed with metric and spinor structure so that one can define various metric related differential operators, say Dirac operators, appearing in the field equations of the theory [1]

Identification of Kähler function

The evolution of these basic ideas has been rather slow but has gradually led to a rather beautiful vision. One of the key problems has been the definition of Kähler function. Kähler function is Kähler action for a preferred extremal assignable to a given 3-surface but what this preferred extremal is? The obvious first guess was as absolute minimum of Kähler action but could not be proven to be right or wrong. One big step in the progress was boosted by the idea that TGD should reduce to almost topological QFT in which braids would replace 3-surfaces in finite measurement resolution, which could be inherent property of the theory itself and imply discretization at partonic 2-surfaces with discrete points carrying fermion number.

It took long time to realize that there is no discretization in 4-D sense - this would lead to difficulties with basic symmetries. Rather, the discretization occurs for the parameters characterizing co-dimension 2 objects representing the information about space-time surface so that they belong to some algebraic extension of rationals. These 2-surfaces - string world sheets and partonic 2-surfaces - are genuine physical objects rather than a computational approximation. Physics itself approximates itself, one might say! This is of course nothing but strong form of holography.

1. TGD as almost topological QFT vision suggests that Kähler action for preferred extremals reduces to Chern-Simons term assigned with space-like 3-surfaces at the ends of space-time (recall the notion of causal diamond (CD)) and with the light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. Minkowskian and Euclidian regions would give at wormhole throats the same contribution apart from coefficients and in Minkowskian regions the $\sqrt{g_4}$ factorc coming from metric would be imaginary so that one would obtain sum of real term identifiable as Kähler function and imaginary term identifiable as the ordinary Minkowskian action giving rise to interference effects and stationary phase approximation central in both classical and quantum field theory.

   Imaginary contribution - the presence of which I realized only after 33 years of TGD - could also have topological interpretation as a Morse function. On physical side the emergence of Euclidian space-time regions is something completely new and leads to a dramatic modification of the ideas about black hole interior.

2. The way to achieve the reduction to Chern-Simons terms is simple. The vanishing of Coulomb contribution to Kähler action is required and is true for all known extremals if one makes a general ansatz about the form of classical conserved currents. The so called weak form of electric-magnetic duality defines a boundary condition reducing the resulting 3-D terms to Chern-Simons terms. In this way almost topological QFT results. But only "almost" since the Lagrange multiplier term forcing electric-magnetic duality implies that Chern-Simons action for preferred extremals depends on metric.

WCW spinor fields

Classical WCW spinor fields are analogous to Schrödinger amplitudes and the construction of WCW Kähler geometry reduces to the second quantization of free spinor fields of H.

[1] There are four kinds of Dirac operators in TGD. The geometrization of quantum theory requires Kähler metric definable either in terms of Kähler function identified as a the bosonic action for Euclidian space-time regions or as anti-commutators for WCW gamma matrices identified as conformal Noether super-charges associated with the second quantized modified Dirac action consisting of string world sheet term and possibly also modified Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

1. The WCW metric is given by anticommutators of WCW gamma matrices which also have interpretation as supercharges assignable to the generators of WCW isometries and allowing expression as non-conserved Noether charges. Holography implies zero energy ontology (ZEO) meaning that zero energy states are superpositions of Bohr orbits connecting boundaries of causal diamond (CD). CDs form a fractal hierarchy and their space forming the spine of WCW is finite-dimensional and can be geometrized. The alternative interpretation is as a superposition of pairs of ordinary 3-D fermionic states assignable to the ends of the space-time surfaces.

2. There are several Dirac operators. WCW Dirac operator D_{WCW} appears in Super-symplectic gauge conditions analogous to Super Virasoro conditions. The algebraic variant of the H Dirac operator D_H appears in fermionic correlation functions: this is due to the fact that free fermions appearing as building bricks of WCW gamma matrices are modes of D_H. The modes of $_DH$ define the ground states of super-symplectic representations. There is also the modified Dirac operator D_{X^4} acting on the induced spinors at space-time surfaces and it is dictated by symmetry one the action fixing the space-time surfaces as Bohr orbits is fixed. D_H is needed since it determines the expressions of WCW gamma matrices as Noether charges assignable to 3-surfaces at the ends of WCW.

The role of modified Dirac action

1. By quantum classical correspondence, the construction of WCW spinor structure in sectors assignable to CDs reduces to the second quantization of the induced spinor fields of H. The basic action is so called modified Dirac action in which gamma matrices are replaced with the modified) gamma matrices defined as contractions of the canonical momentum currents of the bosonic action defining the space-time surfaces with the embedding space gamma matrices. In this way one achieves super-conformal symmetry and conservation of fermionic currents among other things and a consistent Dirac equation.

   Modified Dirac action is needed to define WCW gamma matrices as super charges assignable to WCW isometry generators identified as generators of symplectic transformations and by holography are needed only at the 3-surface at the boundaries of WCW. It is important to notice that the modified Dirac equation does not determine propagators since induced spinor fields are obtained from free second quantized spinor fields of H. This means enormous simplification and makes the theory calculable.

2. An important interpretational problem relates to the notion of the induced spinor connection. The presence of classical W boson fields is in conflict with the classical conservation of em charge since the coupling to classical W fields changes em charge.

   One way out of the problem is the fact that the quantum averages of weak and gluon fields vanish unlike the quantum average of the em field. This leads to a rather precise understanding of electroweak symmetry breaking as being due the fact that color symmetries rotate space-time surfaces and also affect the induced weak fields.

   One can also consider a stronger condition. If one requires that the spinor modes have well-defined em charge, one must assume that the modes in the generic situation are localized at 2-D surfaces - string world sheets or perhaps also partonic 2-surfaces - at which classical W boson fields vanish. Covariantly constant right handed neutrinos generating super-symmetries forms an exception. The vanishing of the Z^0 field is possible for Kähler-Dirac action and should hold true at least above weak length scales. This implies that the string model in 4-D space-time becomes part of TGD. Without these conditions classical weak fields can vanish above weak scale only for the GRT limit of TGD for which gauge potentials are sums over those for space-time sheets.

   The localization would simplify the mathematics enormously and one can solve exactly the Kähler-Dirac equation for the modes of the induced spinor field just like in super string models.

   At the light-like 3-surfaces the signature of the induced metric changes from Euclidian to Minkowskian so that $\sqrt{g_4}$ vanishes. One can pose the condition that the algebraic analog of the massless Dirac equation is satisfied by the modes of the modified-Dirac action assignable to the Chern-Simons-Kähler action.

1.1.5 Construction of scattering amplitudes

Reduction of particle reactions to space-time topology

Particle reactions are identified as topology changes [A18, A22, A26]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. Classically this corresponds to a path of WCW leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

During years this naïve and very rough vision has of course developed a lot and is not anymore quite equivalent with the original insight. In particular, the space-time correlates of Feynman graphs have emerged from theory as Euclidian space-time regions and the strong form of General Coordinate Invariance has led to a rather detailed and in many respects un-expected visions. This picture forces to give up the idea about smooth space-time surfaces and replace space-time surface with a generalization of Feynman diagram in which vertices represent the failure of manifold property. I have also introduced the word "world of classical worlds" (WCW) instead of rather formal "configuration space". I hope that "WCW" does not induce despair in the reader having tendency to think about the technicalities involved!

Construction of the counterparts of S-matrices

What does one mean with the counterpart of S-matrix in the TGD framework has been a long standing problem. The development of ZEO based quantum measurement theory has led to a rough overall view of the situation.

1. There are two kinds of state function reductions (SFRs). "Small" SFRs (SSFRs) following the TGD counterpart of a unitary time evolution defines a sequence of SFRs, which is analogous to a sequence of repeated quantum measurements associated with the Zeno effect. In wave mechanics nothing happens in these measurements. In quantum optics these measurements correspond to weak measurements. In TGD SSFR affects the zero energy state but leaves the 3-D state at the passive boundary of CD unaffected.

2. In TGD framework each SSFR is preceded by a counterpart of a unitary time evolution, which means dispersion in the space of CDs and unitary time evolution in fermionic degrees of freedom such that the passive boundary of CDs and 3-D states at it are unaffected but a superposition of CDs with varying active boundaries in the space of CDs is formed. In SSFR a localization in the space of CDs occurs such that the active is fixed. In a statistical sense the size of the CD increases and the increasing distance between the tips of the CD gives rise to the arrow of geometric time.

3. Also "big" SFRS (BSFRs) can occur and they correspond to ordinary SFRs. In BSFR the roles of the active and passive boundary are changed and this means that the arrow of time is changed. Big SFR occurs when the SSFR corresponds to a quantum measurement, which does not commute with the operators, which define the states at the passive boundary of CD as their eigenstates. This means a radical deviation from standard quantum measurement theory and has predictions in all scales.

4. One can assign the counterpart of S-matrix to the unitary time evolution between two subsequent SSFRs and also to the counterpart of S-matrix associated with BSFR. At least in the latter case the dimension of the state space can increase since at least BSFRs lead to the increase of the dimension of algebraic extension of rationals assignable to the space-time surface by $M^8 - H$ duality. Unitarity is therefore replaced with isometry.

5. I have also considered the possibility that unitary S-matrix could be replaced in the fermionic degrees of freedom with Kähler metric of the state space satisfying analogs of unitarity conditions but it seems that this is un-necessary and also too outlandish an idea.

The notion of M-matrix

1. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operators associated with WCWs associated with the spaces of CDs with fixed passive boundary: this would define an S-matrix assignable to SFR. Also the analog of S-matrix for the localizations of the states to the active boundary assignable to the BSFR changing the state at the passive boundary of CD is needed.

2. If one allows entanglement between positive and energy parts of the zero energy state but assumes that the states at the passive boundary are fixed, one must introduce the counterpart of the density matrix, or rather its square root. This classical free field theory would dictate what I have called M-matrices defined between positive and negative energy parts of zero energy states which form orthonormal rows of what I call U-matrix as a matrix defined between zero energy states. A biven M-matrix in turn would decompose to a product of a hermitian square root of density matrix and unitary S-matrix.

3. M-matrix would define time-like entanglement coefficients between positive and negative energy parts of zero energy states (all net quantum numbers vanish for them) and can be regarded as a hermitian square root of density matrix multiplied by a unitary S-matrix. Quantum theory would be in a well-defined sense a square root of thermodynamics. The orthogonality and hermiticity of the M-matrices commuting with S-matrix means that they span infinite-dimensional Lie algebras acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in a well-defined sense.

4. In fact the Lie algebra of Hermitian M-matrices extends to Kac-Moody type algebra obtained by multiplying hermitian square roots of density matrices with powers of the S-matrix. Also the analog of Yangian algebra involving only non-negative powers of S-matrix is possible and would correspond to a hierarchy of CDs with the temporal distances between tips coming as integer multiples of the CP_2 time.

   The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to a representation matrix of scaling: $S(n) = S^n$, where S is unitary S-matrix associated with the minimal CD [K63]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

5. I have also considered the notion of U-matrix. U-matrix elements between M-matrices for various CDs are proportional to the inner products $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2} \lambda]$, where λ represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and H^i form an orthonormal basis of Hermitian square roots of density matrices. $\circ$ tells that S acts at the active boundary of CD only. I have proposed a general representation for the U-matrix, reducing its construction to that of the S-matrix.

1.1.6 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space ("world of classical worlds", WCW), p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. The fourth thread deserves the name "TGD as a generalized number theory". It involves three separate threads: the fusion of real and various p-adic physics to a single coherent whole by requiring number theoretic universality discussed already, the formulation of quantum TGD in terms of complexified counterparts of classical number fields, and the notion of infinite prime. Note that one can identify subrings such as hyper-quaternions and hyper-octonions as sub-spaces of complexified classical number fields with Minkowskian signature of the metric defined by the complexified inner product.

The Threads in the Development of Quantum TGD

The development of TGD has involved several strongly interacting threads: physics as infinite-dimensional geometry; TGD as a generalized number theory, the hierarchy of Planck constants interpreted in terms of dark matter hierarchy, and TGD inspired theory of consciousness. In the following these threads are briefly described.

1. Quantum T(opological) G(eometro)D(ynamics) as a classical spinor geometry for infinite-dimensional WCW, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness and of quantum biology have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

2. The discussions with Tony Smith initiated a fourth thread which deserves the name "TGD as a generalized number theory". The basic observation was that classical number fields might allow a deeper formulation of quantum TGD. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and rather fruitful revision of the basic views about what the final form and physical content of quantum TGD might be. Together with the vision about the fusion of p-adic and real physics to a larger coherent structure these sub-threads fused to the "physics as generalized number theory" thread.

3. A further thread emerged from the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and strongly suggested by the failure of strict determinism for the fundamental variational principle. The identification of hierarchy of Planck constants labelling phases of dark matter would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

The chronology based identification of the threads is quite natural but not logical and it is much more logical to see p-adic physics, the ideas related to classical number fields, and infinite primes as sub-threads of a thread which might be called "physics as a generalized number theory". In the following I adopt this view. This reduces the number of threads to three corresponding to geometric, number theoretic and topological views of physics.

TGD forces the generalization of physics to a quantum theory of consciousness, and TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations.

Number theoretic vision very briefly

Number theoretic vision about quantum TGD involves notions like adelic physics, M^8-H duality and number theoretic universality. A short review of the basic ideas that have developed during years is in order.

1. The physical interpretation of M^8 is as an analog of momentum space and M^8-H duality is analogous to momentum-position duality of ordinary wave mechanics.

2. Adelic physics means that all classical number fields, all p-adic number fields and their extensions induced by extensions of rationals and defining adeles, and also finite number fields are basic mathematical building bricks of physics.

   The complexification of M^8, identified as complexified octonions, would provide a realization of this picture and M^8-H duality would map the algebraic physics in M^8 to the ordinary physics in $M^4 \times CP_2$ described in terms of partial differential equations.

3. Negentropy Maximization Principle (NMP) states that the conscious information assignable with cognition representable measured in terms of p-adic negentropy increases in statistical sense.

   NMP is mathematically completely analogous to the second law of thermodynamics and number theoretic evolution as an unavoidable statistical increase of the dimension of the algebraic extension of rationals characterizing a given space-time region implies it. There is no paradox involved: the p-adic negentropy measures the conscious information assignable to the entanglement of two systems regarded as a conscious entity whereas ordinary entropy measures the lack of information about the quantums state of either entangled system.

4. Number theoretical universality requires that space-time surfaces or at least their M^8-H duals in M_c^8 are defined for both reals and various p-adic number fields. This is true if they are defined by polynomials with integer coefficients as surfaces in M^8 obeying number theoretic holography realized as associativity of the normal space of 4-D surface using as holographic data 3-surfaces at mass shells identified in terms of roots of a polynomial. A physically motivated additional condition is that the coefficients of the polynomials are smaller than their degrees.

5. Galois confinement is a key piece of the number theoretic vision. It states that the momenta of physical states are algebraic integers in the extensions of rationals assignable to the space-time region considered. These numbers are in general complex and are not consistent with particle in box quantization. The proposal is that physical states satisfy Galois confinement being thus Galois singlets and having therefore total momenta, whose components are ordinary integers, when momentum unit defined by the scale of causal diamond (CD) is used.

6. The notion of p-adic prime was introduced in p-adic mass calculations that started the developments around 1995. p-Adic length scale hypothesis states that p-adic primes near powers of 2 have a special physical role (as possibly also the powers of other small primes such as $p=3$).

   The proposal is that p-adic primes correspond to ramified primes assignable to the extension and identified as divisors of the polynomial defined by the products of the root differences for the roots of the polynomial defining space-time space and having interpretation as values of, in general complex, virtual mass squared.

p-Adic TGD and fusion of real and p-adic physics to single coherent whole

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzles and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired "Universe as Computer" vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

In string model context one tries to reduces the physics to Planck scale. The price is the inability to say anything about physics in long length scales. In TGD p-adic physics takes care of this shortcoming by predicting the physics also in long length scales.

There were many interpretational and technical questions crying for a definite answer.

1. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *the* Physics? Should one perform p-adicization also at the level of the WCW? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations.

2. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question. Quite recently I however learned that the problem of making sense about p-adic integration has been for decades central problem in the frontier of mathematics and a lot of profound work has been done along same intuitive lines as I have proceeded in TGD framework. The basic idea is certainly the notion of algebraic continuation from the world of rationals belonging to the intersection of real world and various p-adic worlds.

Despite various uncertainties, the number of the applications of the poorly defined p-adic physics has grown steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

The key challenge is to fuse various p-adic physics and real physics to single larger structure. This has inspired a proposal for a generalization of the notion of number field by fusing real numbers and various p-adic number fields and their extensions along rationals and possible common algebraic numbers. This leads to a generalization of the notions of embedding space and space-time concept and one can speak about real and p-adic space-time sheets. One can talk about adelic space-time, embedding space, and WCW.

The corresponds of real 4-surfaces with the p-adic ones is induced by number theoretical discretization using points of 4-surfaces $Y^4 \subset M^8_c$ identifiable as 8-momenta, whose components are assumed to be algebraic integers in an extension of rationals defined by the extension of rationals associated with a polynomial P with integer coefficients smaller than the degree of P. These points define a cognitive representation, which is universal in the sense that it exists also in the algebraic extensions of p-adic numbers. The points of the cognitive representations associated with the mass shells with mass squared values identified as roots of P are enough since M^8-H duality can be used at both M^8 and H sides and also in the p-adic context. The mass shells are special in that they allow for Minkowski coordinates very large cognitive representations unlike the interiors of the 4-surfaces determined by holography by using the data defined by the 3-surfaces at the mass shells. The higher the dimension of the algebraic extension associated with P, the better the accuracy of the cognitive representation.

Adelization providing number theoretical universality reduces to algebraic continuation for the amplitudes from this intersection of reality and various p-adicities - analogous to a back of a book - to various number fields. There are no problems with symmetries but canonical identification is needed: various group invariant of the amplitude are mapped by canonical identification to various p-adic number fields. This is nothing but a generalization of the mapping of the p-adic mass squared to its real counterpart in p-adic mass calculations.

This leads to surprisingly detailed predictions and far reaching conjectures. For instance, the number theoretic generalization of entropy concept allows negentropic entanglement central for the applications to living matter (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). One can also understand how preferred p-adic primes could emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K58].

The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to “mind stuff”, the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably a brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

Infinite primes

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory.

After the realization that infinite primes can be mapped to polynomials possibly representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of complexified quaternions and octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

The infinite primes at the first level of hierarchy, which represent analogs of bound states, can be mapped to irreducible polynomials, which in turn characterize the algebraic extensions of rationals defining a hierarchy of algebraic physics continuable to real and p-adic number fields. The products of infinite primes in turn define more general algebraic extensions of rationals. The interesting question concerns the physical interpretation of the higher levels in the hierarchy of infinite primes and integers mappable to polynomials of $n > 1$ variables.

1.1.7 An explicit formula for $M^8 - H$ duality

$M^8 - H$ duality is a generalization of momentum-position duality relating the number theoretic and geometric views of physics in TGD and, despite that it still involves poorly understood aspects, it has become a fundamental building block of TGD. One has 4-D surfaces $Y^4 \subset M^8_c$, where M^8_c is complexified M^8 having interpretation as an analog of complex momentum space and 4-D spacetime surfaces $X^4 \subset H = M^4 \times CP_2$. M^8_c, equivalently E^8_c, can be regarded as complexified octonions. M^8_c has a subspace M^4_c containing M^4.

Comment: One should be very cautious with the meaning of "complex". Complexified octonions involve a complex imaginary unit i commuting with the octonionic imaginary units I_k. i is assumed to also appear as an imaginary unit also in complex algebraic numbers defined by the roots of polynomials P defining holographic data in M^8_c.

In the following $M^8 - H$ duality and its twistor lift are discussed and an explicit formula for the dualities are deduced. Also possible variants of the duality are discussed.

Holography in H

$X^4 \subset H$ satisfies holography and is analogous to the Bohr orbit of a particle identified as a 3-surface. The proposal is that holography reduces to a 4-D generalization of holomorphy so that X^4 is a simultaneous zero of two functions of complex CP_2 coordinates and of what I have called Hamilton-Jacobi coordinates of M^4 with a generalized Kähler structure.

The simplest choice of the Hamilton-Jacobi coordinates is defined by the decomposition $M^4 = M^2 \times E^2$, where M^2 is endowed with hypercomplex structure defined by light-like coordinates (u, v), which are analogous to z and $\overline{z}$. Any analytic map $u \to f(u)$ defines a new set of light-like coordinates and corresponds to a solution of the massless d'Alembert equation in M^2. E^2 has some complex coordinates with imaginary unit defined by i.

The conjecture is that also more general Hamilton-Jacobi structures for which the tangent space decomposition is local are possible. Therefore one would have $M^4 = M^2(x) \times E^2(x)$. These would correspond to non-equivalent complex and Kähler structures of M^4 analogous to those possessed by 2-D Riemann surfaces and parametrized by moduli space.

Number theoretic holography in M^8_c

$Y^4 \subset M^8_c$ satisfies number theoretic holography defining dynamics, which should reduce to associativity in some sense. The Euclidian complexified normal space $N^4(y)$ at a given point y of Y^4 is required to be associative, i.e. quaternionic. Besides this, $N^4(i)$ contains a preferred complex Euclidian 2-D subspace $Y^2(y)$. Also the spaces $Y^2(x)$ define an integrable distribution. I have assumed that $Y^2(x)$ can depend on the point y of Y^4.

These assumptions imply that the normal space $N(y)$ of Y^4 can be parameterized by a point of $CP_2 = SU(3)/U(2)$. This distribution is always integrable unlike quaternionic tangent space distributions. M^8-H duality assigns to the normal space $N(y)$ a point of CP_2. M^4_c point y is mapped to a point $x \in M^4 \subset M^4 \times CP_2$ defined by the real part of its inversion (conformal transformation): this formula involves effective Planck constant for dimensional reasons.

The 3-D holographic data, which partially fixes 4-surfaces Y^4 is partially determined by a polynomial P with real integer coefficients smaller than the degree of P. The roots define mass squared values which are in general complex algebraic numbers and define complex analogs of mass shells in $M^4_c \subset M^8_c$, which are analogs of hyperbolic spaces H^3. The 3-surfaces at these mass shells define 3-D holographic data continued to a surface Y^4 by requiring that the normal space of Y^4 is associative, i.e. quaternionic. These 3-surfaces are not completely fixed but an interesting conjecture is that they correspond to fundamental domains of tessellations of H^3.

What does the complexity of the mass shells mean? The simplest interpretation is that the space-like M^4 coordinates (3-momentum components) are real whereas the time-like coordinate (energy) is complex and determined by the mass shell condition. One would have $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3 when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as a time coordinate. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to an equation of mass shell when $\sqrt{(Re(E)^2 - Im(E)^2)}$, expressed in terms of $Re(E)$, is taken as new energy coordinate $E_{eff} = \sqrt{(Re(E)^2 - Im(E)^2)}$. Is this deformation of H^3 in imaginary time direction equivalent with a region of the hyperbolic 3-space H^3?

One can look at the formula in more detail. Mass shell condition gives $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3, when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as an effective energy. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to a dispersion relation for $Re(E)^2$.

$$Re(E)^2 = \frac{1}{2}(Re(m^2) - Im(m^2) + p^2)(1 \pm \sqrt{1 + \frac{2Im(m^2)^2}{(Re(m^2) - Im(m^2) + p^2)^2}} . \quad (1.1.1)$$

Only the positive root gives a non-tachyonic result for $Re(m^2) - Im(m^2) > 0$. For real roots with $Im(m^2) = 0$ and at the high momentum limit the formula coincides with the standard formula. For $Re(m^2) = Im(m^2)$ one obtains $Re(E)^2 \to Im(m^2)/\sqrt{2}$ at the low momentum limit $p^2 \to 0$. Energy does not depend on momentum at all: the situation resembles that for plasma waves.

Can one find an explicit formula for $M^8 - H$ duality?

The dream is an explicit formula for the $M^8 - H$ duality mapping $Y^4 \subset M^8_c$ to $X^4 \subset H$. This formula should be consistent with the assumption that the generalized holomorphy holds true for X^4.

The following proposal is a more detailed variant of the earlier proposal for which Y^4 is determined by a map g of $M^4_c \to SU(3)_c \subset G_{2,c}$, where $G_{2,c}$ is the complexified automorphism group of octonions and $SU(3)_c$ is interpreted as a complexified color group.

This map defines a trivial $SU(3)_c$ gauge field. The real part of g however defines a non-trivial real color gauge field by the non-linearity of the non-abelian gauge field with respect to the gauge potential. The quadratic terms involving the imaginary part of the gauge potential give an additional condition to the real part in the complex situation and cancel it. If only the real part of g contributes, this contribution would be absent and the gauge field is non-vanishing.

How could the automorphism $g(x) \subset SU(3) \subset G_2$ give rise to $M^8 - H$ duality?

1. The interpretation is that $g(y)$ at given point y of Y^4 relates the normal space at y to a fixed quaternionic/associative normal space at point y_0, which corresponds is fixed by some subgroup $U(2)_0 \subset SU(3)$. The automorphism property of g guarantees that the normal space is quaternionic/associative at y. This simplifies the construction dramatically.

2. The quaternionic normal sub-space (which has Euclidian signature) contains a complex sub-space which corresponds to a point of sphere $S^2 = SO(3)/O(2)$, where $SO(3)$ is the quaternionic automorphism group. The interpretation could be in terms of a selection of spin quantization axes. The local choice of the preferred complex plane would not be unique and is analogous to the possibility of having non-trivial Hamilton Jacobi structures in M^4 characterized by the choice of $M^2(x)$ and equivalently its normal subspace $E^2(x)$.

   These two structures are independent apart from dependencies forced by the number theoretic dynamics. Hamilton-Jacobi structure means a selection of the quantization axis of spin and energy by fixing a distribution of light-like tangent vectors of M^4 and the choice of the quaternionic normal sub-space fixes a choice of preferred quaternionic imaginary unit defining a quantization axis of the weak isospin.

3. The real part $Re(g(y))$ defines a point of $SU(3)$ and the bundle projection $SU(3) \to CP_2$ in turn defines a point of $CP_2 = SU(3)/U(2)$. Hence one can assign to g a point of CP_2 as $M^8 - H$ duality requires and deduce an explicit formula for the point. This means a realization of the dream.

4. The construction requires a fixing of a quaternionic normal space N_0 at y_0 containing a preferred complex subspace at a single point of Y^4 plus a selection of the function g. If M^4 coordinates are possible for Y^4, the first guess is that g as a function of complexified M^4 coordinates obeys generalized holomorphy with respect to complexified M^4 coordinates in the same sense and in the case of X^4. This might guarantee that the $M^8 - H$ image of Y^4 satisfies the generalized holomorphy.

5. Also space-time surfaces X^4 with M^4 projection having a dimension smaller than 4 are allowed. I have proposed that they might correspond to singular cases for the above formula: a kind of blow-up would be involved. One can also consider a more general definition of Y^4 allowing it to have a M^4 projection with dimension smaller than 4 (say cosmic strings). Could one have implicit equations for the surface Y^4 in terms of the complex coordinates of $SU(3)_c$ and M^4? Could this give for instance cosmic strings with a 2-D M^4 projection and CP_2 type extremals with 4-D CP_2 projection and 1-D light-like M^4 projection?

What could the number theoretic holography mean physically?

What could be physical meaning of the number theoretic holography? The condition that has been assumed is that the CP_2 coordinates at the mass shells of $M^4_c \subset M^8_c$ mapped to mass shells H^3 of $M^4 \subset M^4 \times CP_2$ are constant at the H^3. This is true if the $g(y)$ defines the same CP_2 point for a given component X^3_i of the 3-surface at a given mass shell. g is therefore fixed apart from a local $U(2)$ transformation leaving the CP_2 point invariant. A stronger condition would be that the CP_2 point is the same for each component of X^3_i and even at each mass shell but this condition seems to be unnecessarily strong.

Comment: One can o criticize this condition as too strong and one can consider giving up this condition. The motivation for this condition is that the number of algebraic points at the 3-surfaces associated with H^3 explodes since the coordinates associated with normal directions vanish. Kind of cognitive explosion would be in question.

$SU(3)$ corresponds to a subgroup of G_2 and one can wonder what the fixing of this subgroup could mean physically. G_2 is 14-D and the coset space $G_2/SU(3)$ is 6-D and a good guess is that it is just the 6-D twistor space $SU(3)/U(1) \times U(1)$ of CP_2: at least the isometries are the same. The fixing of the $SU(3)$ subgroup means fixing of a CP_2 twistor. Physically this means the fixing of the quantization axis of color isospin and hypercharge.

Twistor lift of the holography

What is interesting is that by replacing $SU(3)$ with G_2, one obtains an explicit formula form the generalization of $M^8 - H$ duality to that for the twistorial lift of TGD!

One can also consider a twistorial generalization of the above proposal for the number theoretic holography by allowing local G_2 automorphisms interpreted as local choices of the color quantization axis. G_2 elements would be fixed apart from a local $SU(3)$ transformation at the components of 3-surfaces at mass shells. The choice of the color quantization axes for a connected 3-surface at a given mass shell would be the same everywhere. This choice is indeed very natural physically since 3-surface corresponds to a particle.

Is this proposal consistent with the boundary condition of the number theoretical holography mean in the case of 4-surfaces in M^8_c and $M^4 \times CP_2$?

1. The selection of $SU(3) \subset G_2$ for ordinary $M^8 - H$ duality means that the $G_{2,c}$ gauge field vanishes everywhere and the choice of color quantization axis is the same at all points of the 4-surface. The fixing of the CP_2 point to be constant at H^3 implies that the color gauge field at $H^3 \subset M^8_c$ and its image $H^3 \subset H$ vanish. One would have color confinement at the mass shells H^3_i, where the observations are made. Is this condition too strong?

2. The constancy of the G_2 element at mass shells makes sense physically and means a fixed color quantization axis. The selection of a fixed $SU(3) \subset G_2$ for entire space-time surface is in conflict with the non-constancy of G_2 element unless G_2 element differs at different points of 4-surface only by a multiplication of a local $SU(3)_0$ element, that is local $SU(3)$ transformation. This kind of variation of the G_2 element would mean a fixed color group but varying choice of color quantization axis.

3. Could one consider the possibility that the local $G_{2,c}$ element is free and defines the twistor lift of $M^8 - H$ duality as something more fundamental than the ordinary $M^8 - H$ duality based on $SU(3)_c$. This duality would make sense only at the mass shells so that only the spaces $H^3 \times CP_2$ assignable to mass shells would make sense physically? In the interior CP_2 would be replaced with the twistor space $SU(3)/U(1) \times U(1)$. Color gauge fields would be non-vanishing at the mass shells but outside the mass shells one would have G_2 gauge fields.

   There is also a physical objection against the G_2 option. The 14-D Lie algebra representation of G_2 acts on the imaginary octonions which decompose with respect to the color group to $1 \oplus 3 \oplus \overline{3}$. The automorphism property requires that 1 can be transformed to 3 or $\overline{3}$ to themselves: this requires that the decomposition contains $3 \oplus \overline{3}$. Furthermore, it must be possible to transform 3 and $\overline{3}$ to themselves, which requires the presence of 8. This leaves only the decomposition $8 \oplus 3 \oplus \overline{3}$. G_2 gluons would both color octet and triplets. In the TDG framework the only conceivable interpretation would be in terms of ordinary gluons and leptoquark-like gluons. This does not fit with the basic vision of TGD.

The choice of twistor as a selection of quantization axes should make sense also in the M^4 degrees of freedom. M^4 twistor corresponds to a choice of light-like direction at a given point of M^4. The spatial component of the light-like vector fixes the spin quantization axis. Its choice together with the light-likeness fixes the time direction and therefore the rest system and energy quantization axis. Light-like vector fixes also the choice of M^2 and of E^2 as its orthogonal complement. Therefore the fixing of M^4 twistor as a point of $SU(4)/SU(3) \times U(1)$ corresponds to a choice of the spin quantization axis and the time-like axis defining the rest system in which the energy is measured. This choice would naturally correspond to the Hamilton-Jacobi structure fixing the decompositions $M^2(x) \times E^2(x)$. At a given mass shell the choice of the quantization axis would be constant for a given X^3_i.

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark Matter as Large $\hbar$ Phases

D. Da Rocha and Laurent Nottale [E1] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests that astrophysical systems are at some levels of the hierarchy of space-time sheets macroscopic quantum systems. The space-time sheets in question would carry dark matter.

Nottale's hypothesis would predict a gigantic value of h_{gr}. Equivalence Principle and the independence of gravitational Compton length on mass m implies however that one can restrict the values of mass m to masses of microscopic objects so that h_{gr} would be much smaller. Large h_{gr} could provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K88].

It is natural to assign the values of Planck constants postulated by Nottale to the space-time sheets mediating gravitational interaction and identifiable as magnetic flux tubes (quanta) possibly carrying monopole flux and identifiable as remnants of cosmic string phase of primordial cosmology. The magnetic energy of these flux quanta would correspond to dark energy and magnetic tension would give rise to negative "pressure" forcing accelerate cosmological expansion. This leads to a rather detailed vision about the evolution of stars and galaxies identified as bubbles of ordinary and dark matter inside magnetic flux tubes identifiable as dark energy.

Certain experimental findings suggest the identification $h_{eff} = n\times = h_{gr}$. The large value of h_{gr} can be seen as a way to reduce the string tension of fermionic strings so that gravitational (in fact all!) bound states can be described in terms of strings connecting the partonic 2-surfaces defining particles (analogous to AdS/CFT description). The values $h_{eff}/h = n$ can be interpreted in terms of a hierarchy of breakings of super-conformal symmetry in which the super-conformal generators act as gauge symmetries only for a sub-algebras with conformal weights coming as multiples of n. Macroscopic quantum coherence in astrophysical scales is implied. If also Kähler-Dirac action is present, part of the interior degrees of freedom associated with the Kähler-Dirac part of conformal algebra become physical. A possible is that tfermionic oscillator operators generate super-symmetries and sparticles correspond almost by definition to dark matter with $h_{eff}/h = n > 1$. One implication would be that at least part if not all gravitons would be dark and be observed only through their decays to ordinary high frequency graviton ($E = hf_{high} = h_{eff}f_{low}$) of bunch of n low energy gravitons.

Hierarchy of Planck Constants from the Anomalies of Neuroscience and Biology

The quantal ELF effects of ELF em fields on vertebrate brain have been known since seventies. ELF em fields at frequencies identifiable as cyclotron frequencies in magnetic field whose intensity is about 2/5 times that of Earth for biologically important ions have physiological effects and affect also behavior. What is intriguing that the effects are found only in vertebrates (to my best knowledge). The energies for the photons of ELF em fields are extremely low - about 10^{-10} times lower than thermal energy at physiological temperatures- so that quantal effects are impossible in the framework of standard quantum theory. The values of Planck constant would be in these situations large but not gigantic.

This inspired the hypothesis that these photons correspond to so large a value of Planck constant that the energy of photons is above the thermal energy. The proposed interpretation was as dark photons and the general hypothesis was that dark matter corresponds to ordinary matter with non-standard value of Planck constant. If only particles with the same value of Planck constant can appear in the same vertex of Feynman diagram, the phases with different value of Planck constant are dark relative to each other. The phase transitions changing Planck constant can however make possible interactions between phases with different Planck constant but these interactions do not manifest themselves in particle physics. Also the interactions mediated by classical fields should be possible. Dark matter would not be so dark as we have used to believe.

The hypothesis $h_{eff} = h_{gr}$ - at least for microscopic particles - implies that cyclotron energies of charged particles do not depend on the mass of the particle and their spectrum is thus universal although corresponding frequencies depend on mass. In bio-applications this spectrum would correspond to the energy spectrum of bio-photons assumed to result from dark photons by h_{eff} reducing phase transition and the energies of bio-photons would be in visible and UV range associated with the excitations of bio-molecules.

Also the anomalies of biology (see for instance [K77, K78, K74]) support the view that dark matter might be a key player in living matter.

Dark Matter as a Source of Long Ranged Weak and Color Fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics.

The recent view about the solutions of Kähler- Dirac action assumes that the modes have a well-defined em charge and this implies that localization of the modes to 2-D surfaces (right-handed neutrino is an exception). Classical W boson fields vanish at these surfaces and also classical Z^0 field can vanish. The latter would guarantee the absence of large parity breaking effects above intermediate boson scale scaling like h_{eff}.

1.1.9 Twistors in TGD and connection with Veneziano duality

The twistorialization of TGD has two aspects. The attempt to generalize twistor Grassmannian approach emerged first. It was however followed by the realization that also the twistor lift of TGD at classical space-time level is needed. It turned out that the progress in the understanding of the classical twistor lift has been much faster - probably this is due to my rather limited technical QFT skills.

Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K101]. The reason is that M^4 and CP_2 are completely exceptional in the sense that they are the only 4-D manifolds allowing twistor space with Kähler structure [A17]. The twistor space of $M^4 \times CP_2$ is Cartesian product of those of M^4 and CP_2. The obvious idea is that space-time surfaces allowing twistor structure if they are orientable are representable as surfaces in H such that the properly induced twistor structure coincides with the twistor structure defined by the induced metric.

In fact, it is enough to generalize the induction of spinor structure to that of twistor structure so that the induced twistor structure need not be identical with the ordinary twistor structure possibly assignable to the space-time surface. The induction procedure reduces to a dimensional reduction of 6-D Kähler action giving rise to 6-D surfaces having bundle structure with twistor sphere as fiber and space-time as base. The twistor sphere of this bundle is imbedded as sphere in the product of twistor spheres of twistor spaces of M^4 and CP_2.

This condition would define the dynamics, and the original conjecture was that this dynamics is equivalent with the identification of space-time surfaces as preferred extremals of Kähler action. The dynamics of space-time surfaces would be lifted to the dynamics of twistor spaces, which are sphere bundles over space-time surfaces. What is remarkable that the powerful machinery of complex analysis becomes available.

It however turned out that twistor lift of TGD is much more than a mere technical tool. First of all, the dimensionally reduction of 6-D Kähler action contained besides 4-D Kähler action also a volume term having interpretation in terms of cosmological constant. This need not bring anything new, since all known extremals of Kähler action with non-vanishing induced Kähler form are minimal surfaces. There is however a large number of embeddings of twistor sphere of space-time surface to the product of twistor spheres. Cosmological constant has spectrum and depends on length scale, and the proposal is that coupling constant evolution reduces to that for cosmological constant playing the role of cutoff length. That cosmological constant could transform from a mere nuisance to a key element of fundamental physics was something totally new and unexpected.

1. The twistor lift of TGD at space-time level forces to replace 4-D Kähler action with 6-D dimensionally reduced Kähler action for 6-D surface in the 12-D Cartesian product of 6-D twistor spaces of M^4 and CP_2. The 6-D surface has bundle structure with twistor sphere as fiber and space-time surface as base.

   Twistor structure is obtained by inducing the twistor structure of 12-D twistor space using dimensional reduction. The dimensionally reduced 6-D Kähler action is sum of 4-D Kähler action and volume term having interpretation in terms of a dynamical cosmological constant depending on the size scale of space-time surface (or of causal diamond CD in zero energy ontology (ZEO)) and determined by the representation of twistor sphere of space-time surface in the Cartesian product of the twistor spheres of M^4 and CP_2.

2. The preferred extremal property as a representation of quantum criticality would naturally correspond to minimal surface property meaning that the space-time surface is separately an extremal of both Kähler action and volume term almost everywhere so that there is no coupling between them. This is the case for all known extremals of Kähler action with non-vanishing induced Kähler form.

   Minimal surface property could however fail at 2-D string world sheets, their boundaries and perhaps also at partonic 2-surfaces. The failure is realized in minimal sense if the 3-surface has 1-D edges/folds (strings) and 4-surface 2-D edges/folds (string world sheets) at which some partial derivatives of the embedding space coordinates are discontinuous but canonical momentum densities for the entire action are continuous.

   There would be no flow of canonical momentum between interior and string world sheet and minimal surface equations would be satisfied for the string world sheet, whose 4-D counterpart in twistor bundle is determined by the analog of 4-D Kähler action. These conditions allow the transfer of canonical momenta between Kähler- and volume degrees of freedom at string world sheets. These no-flow conditions could hold true at least asymptotically (near the boundaries of CD).

   $M^8 - H$ duality suggests that string world sheets (partonic 2-surfaces) correspond to images of complex 2-sub-manifolds of M^8 (having tangent (normal) space which is complex 2-plane of octonionic M^8).

3. Cosmological constant would depend on p-adic length scales and one ends up to a concrete model for the evolution of cosmological constant as a function of p-adic length scale and other number theoretic parameters (such as Planck constant as the order of Galois group): this conforms with the earlier picture.

   Inflation is replaced with its TGD counterpart in which the thickening of cosmic strings to flux tubes leads to a transformation of Kähler magnetic energy to ordinary and dark matter. Since the increase of volume increases volume energy, this leads rapidly to energy minimum at some flux tube thickness. The reduction of cosmological constant by a phase transition however leads to a new expansion phase. These jerks would replace smooth cosmic expansion of GRT. The discrete coupling constant evolution predicted by the number theoretical vision could be understood as being induced by that of cosmological constant taking the role of cutoff parameter in QFT picture [L46].

Twistor lift at the level of scattering amplitudes and connection with Veneziano duality

The classical part of twistor lift of TGD is rather well-understood. Concerning the twistorialization at the level of scattering amplitudes the situation is much more difficult conceptually - I already mentioned my limited QFT skills.

1. From the classical picture described above it is clear that one should construct the 8-D twistorial counterpart of theory involving space-time surfaces, string world sheets and their boundaries, plus partonic 2-surfaces and that this should lead to concrete expressions for the scattering amplitudes.

   The light-like boundaries of string world sheets as carriers of fermion numbers would correspond to twistors as they appear in twistor Grassmann approach and define the analog for the massless sector of string theories. The attempts to understand twistorialization have been restricted to this sector.

2. The beautiful basic prediction would be that particles massless in 8-D sense can be massive in 4-D sense. Also the infrared cutoff problematic in twistor approach emerges naturally and reduces basically to the dynamical cosmological constant provided by classical twistor lift.

   One can assign 4-momentum both to the spinor harmonics of the embedding space representing ground states of super-conformal representations and to light-like boundaries of string world sheets at the orbits of partonic 2-surfaces. The two four-momenta should be identical by quantum classical correspondence: this could be seen as a concretization of Equivalence Principle. Also a connection with string model emerges.

3. As far as symmetries are considered, the picture looks rather clear. Ordinary twistor Grassmannian approach boils down to the construction of scattering amplitudes in terms of Yangian invariants for conformal group of M^4. Therefore a generalization of super-symplectic symmetries to their Yangian counterpart seems necessary. These symmetries would be gigantic but how to deduce their implications?

4. The notion of positive Grassmannian is central in the twistor approach to the scattering amplitudes in $calN = 4$ SUSYs. TGD provides a possible generalization and number theoretic interpretation of this notion. TGD generalizes the observation that scattering amplitudes in twistor Grassmann approach correspond to representations for permutations. Since 2-vertex is the only fermionic vertex in TGD, OZI rules for fermions generalizes, and scattering amplitudes are representations for braidings.

   Braid interpretation encourages the conjecture that non-planar diagrams can be reduced to ordinary ones by a procedure analogous to the construction of braid (knot) invariants by gradual un-braiding (un-knotting).

This is however not the only vision about a solution of non-planarity. Quantum criticality provides different view leading to a totally unexpected connection with string models, actually with the Veneziano duality, which was the starting point of dual resonance model in turn leading via dual resonance models to super string models.

1. Quantum criticality in TGD framework means that coupling constant evolution is discrete in the sense that coupling constants are piecewise constant functions of length scale replaced by dynamical cosmological constant. Loop corrections would vanish identically and the recursion formulas for the scattering amplitudes (allowing only planar diagrams) deduced in twistor Grassmann would involve no loop corrections. In particular, cuts would be replaced by sequences of poles mimicking them like sequences of point charge mimic line charges. In momentum discretization this picture follows automatically.

2. This would make sense in finite measurement resolution realized in number theoretical vision by number-theoretic discretization of the space-time surface (cognitive representation) as points with coordinates in the extension of rationals defining the adele [L35]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?

3. Maybe it is! The basic idea of behind the original Veneziano amplitudes (see `http://tinyurl.com/yyhwvbqb`) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holber-Beck Nielsen, and Leonard Susskind to N-particle amplitude (see `http://tinyurl.com/yyvkx7as`) based on string picture, and the resulting model was called dual resonance model. The model was forgotten as QCD emerged. Later came superstring models and led to M-theory. Now it has become clear that something went wrong, and it seems that one must return to the roots. Could the return to the roots mean a careful reconsideration of the dual resonance model?

4. Recall that Veneziano duality (1968) was deduced by assuming that scattering amplitude can be described as sum over s-channel resonances or t-channel Regge exchanges and Veneziano duality stated that hadronic scattering amplitudes have representation as sums over s- or t-channel resonance poles identified as excitations of strings. The sum over exchanges defined by t-channel resonances indeed reduces at larger values of s to Regge form.

   The resonances had zero width, which was not consistent with unitarity. Further, there were no counterparts for the *sum* of s-, t-, and u-channel diagrams with continuous cuts in the kinematical regions encountered in QFT approach. What puts bells ringing is the u-channel diagrams would be non-planar and non-planarity is the problem of twistor Grassmann approach.

5. Veneziano duality is true only for s- and t- channels but not been s- and u-channel. Stringy description makes t-channel and s-channel pictures equivalent. Could it be that in fundamental description u-channels diagrams cannot be distinguished from s-channel diagrams or t-channel diagrams? Could the stringy representation of the scattering diagrams make u-channel twist somehow trivial if handles of string world sheet representing stringy loops in turn representing the analog of non-planarity of Feynman diagrams are absent? The permutation of external momenta for tree diagram in absence of loops in planar representation would be a twist of π in the representation of planar diagram as string world sheet and would not change the topology of the string world sheet and would not involve non-trivial world sheet topology.

   For string world sheets loops would correspond to handles. The presence of handle would give an edge with a loop at the level of 3-surface (self energy correction in QFT). Handles are not allowed if the induced metric for the string world sheet has Minkowskian signature. If the stringy counterparts of loops are absent, also the loops in scattering amplitudes should be absent.

   This argument applies only inside the Minkowskian space-time regions. If string world sheets are present also in Euclidian regions, they might have handles and loop corrections could emerge in this manner. In TGD framework strings (string world sheets) are identified to 1-D edges/folds of 3-surface at which minimal surface property and topological QFT property fails (minimal surfaces as calibrations). Could the interpretation of edge/fold as discontinuity of some partial derivatives exclude loopy edges: perhaps the branching points would be too singular?

A reduction to a sum over s-channel resonances is what the vanishing of loops would suggest. Could the presence of string world sheets make possible the vanishing of continuous cuts even at the continuum limit so that continuum cuts would emerge only in the approximation as the density of resonances is high enough?

The replacement of continuous cut with a sum of *infinitely* narrow resonances is certainly an approximation. Could it be that the stringy representation as a sum of resonances with *finite* width is an essential aspect of quantum physics allowing to get rid of infinities necessarily accompanying loops? Consider now the arguments against this idea.

1. How to get rid of the problems with unitarity caused by the zero width of resonances? Could *finite* resonance widths make unitarity possible? Ordinary twistor Grassmannian approach predicts that the virtual momenta are light-like but complex: obviously, the imaginary part of the energy in rest frame would have interpretation as resonance with.

   In TGD framework this generalizes for 8-D momenta. By quantum-classical correspondence (QCC) the classical Noether charges are equal to the eigenvalues of the fermionic charges in Cartan algebrable (maximal set of mutually commuting observables) and classical TGD indeed predicts complex momenta (Kähler coupling strength is naturally complex). QCC thus supports this proposal.

2. Sum over resonances/exchanges picture is in conflict with QFT picture about scattering of particles. Could *finite* resonance widths due to the complex momenta give rise to the QFT type scattering amplitudes as one develops the amplitudes in Taylor series with respect to the resonance width? Unitarity condition indeed gives the first estimate for the resonance width.

   QFT amplitudes should emerge in an approximation obtained by replacing the discrete set of finite width resonances with a cut as the distance between poles is shorter than the resolution for mass squared.

   In superstring models string tension has single very large value and one cannot obtain QFT type behavior at low energies (for instance, scattering amplitudes in hadronic string model are concentrated in forward direction). TGD however predicts an entire hierarchy of p-adic length scales with varying string tension. The hierarchy of mass scales corresponding roughly to the lengths and thickness of magnetic flux tubes as thickened cosmic strings and characterized by the value of cosmological constant predicted by twistor lift of TGD. Could this give rise to continuous QCT type cuts at the limit when measurement resolution cannot distinguish between resonances?

   The dominating term in the sum over sums of resonances in t-channel gives near forward direction approximately the lowest mass resonance for strings with the smallest string tension. This gives the behavior $1/(t - m_{min}^2)$, where m_{min} corresponds to the longest mass scale involved (the largest space-time sheet involved), approximating the $1/t$-behavior of massless theories. This also brings in IR cutoff, the lack of which is a problem of gauge theories. This should give rise to continuous QFT type cuts at the limit when measurement resolution cannot distinguish between resonances.

1.2 Bird's Eye of View about the Topics of "Quantum - and Classical Computation in TGD Universe"

This book collects computation related chapters from various books related to TGD. Topological quantum computation using braids consisting of magnetic flux was the first proposal in this direction.The notion of the magnetic body carrying dark matter as phases of ordinary matter with a large value of effective Planck constant serves in the role of boss since the large value of effective Planck constant is analogous to IQ. Zero energy ontology (ZEO) predicts time reversal in the TGD counterparts of state function reductions associated with the ordinary quantum measurements. The advent of AI and eventually GPT inspired the question whether classical computers could become conscious systems in some aspects analogous to quantum computers when the quantum coherence time is longer than the clock periods and statistical determinism fails.

The organization of the book "Quantum - and Classical Computation in TGD Universe" is as follows.

1. In the first part of the book the new physics relevant to biology suggested by TGD and consider a general model for how TGD Universe could act as a topological quantum computer. Two chapters are devoted to the model of DNA as topological quantum computer and the ideas inspired by it. The braiding of magnetic flux tubes making TQC possible is an extremely general concept and therefore one can consider many variants of the model. Moreover, the proposed models certainly contain unrealistic elements. The basic uncertainty relates to the

realization of dark genetic codon. The original proposal based on dark nucleons as 3 quarks states is very probably unrealistic and the most plausible realization is in terms of dark proton triplets.

There is also a chapter devoted to the vision about 3-space as a tensor net, i.e. a network with nodes connected by flux tubes making possible quantum entanglement between nodes possible in arbitrary long length scales due to the hierarchy of Planck constants.

2. In the second part of the book, the notions of classical and quantum computation are compared. Usually these approaches are regarded as unrelated. Statistical determinism is the basic assumption in classical computation but the very possibility to realize predetermined computer programs suggests that phase transitions, which are not strictly deterministic, are involved with the manipulation of bits.

   In the TGD framework zero energy ontology (ZEO) and quantum gravitational coherence, possible even in astrophysical scales, can change the situation. Time evolution for a generic quantum system is a sequence of unitary time evolutions followed by "small" statefunction reductions, whose sequence is the TGD counterpart for Zeno effect.

   If the Compton time assignable to the gravitational Planck constant is longer than the period of the computer clock, it is possible that quantal effects emerge and the computer becomes more like a living conscious entity. This can occur even below the critical clock frequency. This leads to interesting speculations concerning AI and systems like chatGPT.

1.3 Sources

The eight online books about TGD [K107, K102, K82, K66, K22, K64, K49, K91] and nine online books about TGD inspired theory of consciousness and quantum biology [K99, K20, K73, K18, K44, K53, K56, K90, K98] are warmly recommended for the reader willing to get overall view about what is involved.

My homepage (`http://tinyurl.com/ybv8dt4n`) contains a lot of material about TGD. In particular, a TGD glossary at `http://tinyurl.com/yd6jf3o7`).

I have published articles about TGD and its applications to consciousness and living matter in *Journal of Non-Locality* (`http://tinyurl.com/ycyrxj4o` founded by Lian Sidorov and in *Prespacetime Journal* (`http://tinyurl.com/ycvktjhn`), *Journal of Consciousness Research and Exploration* (`http://tinyurl.com/yba4f672`), and *DNA Decipher Journal* (`http://tinyurl.com/y9z52khg`), all of them founded by Huping Hu. One can find the list about the articles published at `http://tinyurl.com/ybv8dt4n`. I am grateful for these far-sighted people for providing a communication channel, whose importance one cannot overestimate.

1.3.1 PART I: TOPOLOGICAL QUANTUM COMPUTATION IN TGD UNIVERSE

Topological Quantum Computation in TGD Universe

Topological quantum computation (TQC) is one of the most promising approaches to quantum computation. The coding of logical qubits to the entanglement of topological quantum numbers promises to solve the de-coherence problem whereas the S-matrices of topological field theories (modular functors) providing unitary representations for braids would give a realization of quantum computer programs with gates represented as simple braiding operations. Because of their effective 2-dimensionality anyon systems are the best candidates for realizing the representations of braid groups.

TGD allows several new insights related to quantum computation. TGD predicts new information measures as number theoretical negative valued entanglement entropies defined for systems having extended rational entanglement and characterizes bound state entanglement as bound state entanglement. Hierarchy of Planck constants labelling phases of dark matter makes possible macroscopic quantum coherence. Negentropy Maximization Principle and p-adic length scale hierarchy of space-time sheets encourage to believe that Universe itself might do its best to resolve the de-coherence problem. The new view about quantum jump suggests strongly the notion of quantum parallel dissipation so that thermalization in shorter length scales would guarantee coherence in longer length scales. The possibility of negative energies and communications to geometric future in turn might even trivialize the problems caused by long computation times: computation could be iterated again and again by turning the computer on in the geometric past and TGD inspired theory of consciousness predicts that something like this occurs routinely in living matter.

Kähler action defines the basic variational principle of classical TGD and predicts extremely complex but non-chaotic magnetic flux tube structures, which can get knotted and linked. The dimension of CP_2 projection for these structures is $D = 3$. These structures are the corner stone of TGD inspired theory of living matter and provide the braid structures needed by TQC.

Anyons are the key actors of TQC and TGD leads to detailed model of anyons as systems consisting of track of a periodically moving charged particle realized as a flux tube containing the particle inside it. This track would be a space-time correlate for the outcome of dissipative processes producing the asymptotic self-organization pattern. These tracks in general carry vacuum Kähler charge which is topologized when the CP_2 projection of space-time sheet is $D = 3$. This explains charge fractionization predicted to occur also for other charged particles. When a system approaches chaos periodic orbits become slightly aperiodic and the correlate is flux tube which rotates N times before closing. This gives rise to Z_N valued topological quantum number crucial for TQC using anyons ($N = 4$ holds true in this case). Non-Abelian anyons are needed by TQC, and the existence of long range classical electro-weak fields predicted by TGD is an essential prerequisite of non-Abelianity.

Negative energies and zero energy states are of crucial importance of TQC in TGD. The possibility of phase conjugation for fermions would resolve the puzzle of matter-antimatter asymmetry in an elegant manner. Anti-fermions would be present but have negative energies. Quite generally, it is possible to interpret scattering as a creation of pair of positive and negative energy states, the latter representing the final state. One can characterize precisely the deviations of this Eastern world view with respect to the Western world view assuming an objective reality with a positive definite energy and understand why the Western illusion apparently works. In the case of TQC the initial *resp.* final state of braided anyon system would correspond to positive *resp.* negative energy state.

The light-like boundaries of magnetic flux tubes are ideal for TQC. The point is that 3-dimensional light-like quantum states can be interpreted as representations for the time evolution of a two-dimensional system and thus represented self-reflective states being "about something". The light-likeness (no geometric time flow) is a space-time correlate for the ceasing of subjective time flow during macro-temporal quantum coherence. The S-matrices of TQC can be coded to these light-like states such that each elementary braid operation corresponds to positive energy anyons near the boundary of the magnetic flux tube A and negative energy anyons with opposite topological charges residing near the boundary of flux tube B and connected by braided threads representing the quantum gate. Light-like boundaries also force Chern-Simons action as the only possible general coordinate invariant action since the vanishing of the metric determinant does not allow any other candidate. Chern-Simons action indeed defines the modular functor for braid coding for a TQC program.

The comparison of the concrete model for TQC in terms of magnetic flux tubes with the structure of DNA gives tantalizing hints that DNA double strand is a topological quantum computer. Strand *resp.* conjugate strand would carry positive *resp.* negative energy anyon systems. The knotting and linking of DNA double strand would code for 2-gates realized as a unique maximally entangling Yang-Baxter matrix R for 2-state system. The pairs A-T, T-A, C-G, G-C in active state would code for the four braid operations of 3-braid group in 1-qubit Temperley Lieb representation associated with quantum group $SL(2)_q$. On basis of this picture one can identify N-O hydrogen bonds between DNA strands as structural correlates of 3-braids responsible for the nontrivial 1-gates whereas N-N hydrogen bonds would be correlates for the return gates acting as identity gates. Depending on whether the nucleotide is active or not it codes for nontrivial 1-gate or for identity gate so that DNA strand can program itself or be programmed dynamically.

The more recent work has demonstrated the the particular physical realization discussed in this chapter is only one possibily, and that braiding naturally generalizes to 2-braiding in TGD framework with braiding defined for string world sheets in 4-D space-time. Zero energy ontology allows also to understand why TQC programs - naturally identiable as biological programs - are selected as those associated with the maxima of Kähler function, which are now space-time surfaces rather than 3-surfaces.

DNA as Topological Quantum Computer

The chapter represents a vision about how DNA might act as a topological quantum computer). TQC means that the braidings of braid strands define TQC programs and M-matrix (generalization of S-matrix in zero energy ontology) defining the entanglement between states assignable to the end points of strands define the TQC usually coded as unitary time evolution for Schrödinger equation.

Before a representation of the model of TQC general vision about what happens in quantum jump, which at least in formal sense can be regarded as quantum computation (TQC), is represented. Included is also a section about possible modification of thermodynamics required by the possibility of negentropic entanglement. The modification corresponds simply to the replacement $S \rightarrow S - N$ for the entropy in standard thermodynamics. The implications of this replacement are however highly non-trivial. The "pessimistic" generalization of the second law allows to understand the thermodynamical aspect of TQC. One can understand why living matter is so effective entropy producer as compared to inanimate matter and also the characteristic decomposition of living systems to highly negentropic and entropic parts as a consequence of generalized second law. ADP-ATP process of metabolism provides a concrete application for the generalized thermodynamics and allows to see this process as a transfer of negentropic entanglement. Also DNA double strand for which sugar-phosphate backbone consists of XMPs, X= A,T,C,G containing negentropy carrying phosphate bonds can be seen as analogous to conscious brain with DNA strands representing right and left hemispheres.

One can end up to the model of TQC in the following manner.

1. Darwinian selection for which the standard theory of self-organization provides a model, should apply also to TQC programs. Tqc programs should correspond to asymptotic self-organization patterns selected by dissipation in the presence of metabolic energy feed. The spatial and temporal pattern of the metabolic energy feed characterizes the TQC program - or equivalently - sub-program call.

2. Since braiding characterizes the TQC program, the self-organization pattern should correspond to a hydrodynamical flow or a pattern of magnetic field inducing the braiding. Braid strands must correspond to magnetic flux tubes of the magnetic body of DNA. If each nucleotide is transversal magnetic dipole it gives rise to transversal flux tubes, which can also connect to the genome of another cell. As a matter fact, the flux tubes would correspond to what I call wormhole magnetic fields having pairs of space-time sheets carrying opposite magnetic fluxes.

3. The output of TQC sub-program is probability distribution for the outcomes of state function reduction so that the sub-program must be repeated very many times. It is represented as four-dimensional patterns for various rates (chemical rates, nerve pulse patterns, EEG power distributions,...) having also identification as temporal densities of zero energy states in various scales. By the fractality of TGD Universe there is a hierarchy of TQCs corresponding to p-adic and dark matter hierarchies. Programs (space-time sheets defining coherence regions) call programs in shorter scale. If the self-organizing system has a periodic behavior each TQC module defines a large number of almost copies of itself asymptotically. Generalized EEG could naturally define this periodic pattern and each period of EEG would correspond to an initiation and halting of TQC. This brings in mind the periodically occurring sol-gel phase transition inside cell near the cell membrane. There is also a connection with hologram idea: EEG rhythm corresponds to reference wave and nerve pulse patters to the wave carrying the information and interfering with the reference wave.

4. Fluid flow must induce the braiding which requires that the ends of braid strands must be anchored to the fluid flow. Recalling that lipid mono-layers of the cell membrane are liquid crystals and lipids of interior mono-layer have hydrophilic ends pointing towards cell interior, it is easy to guess that DNA nucleotides are connected to lipids by magnetic flux tubes and hydrophilic lipid ends are stuck to the flow.

5. The topology of the braid traversing cell membrane cannot be affected by the hydrodynamical flow. Hence braid strands must be split during TQC. This also induces the desired magnetic isolation from the environment. Halting of TQC reconnects them and make possible the communication of the outcome of TQC.

There are several problems related to the details of the realization.

1. How nucleotides A,T,C,G are coded to the strand color and what this color corresponds to physically? There are two options which could be characterized as fermionic and bosonic.

   (a) Magnetic flux tubes having quark and anti-quark at their ends with u,d and u_c, d_c coding for A,G and T,C. CP conjugation would correspond to conjugation for DNA nucleotides.

   (b) Wormhole magnetic flux tubes having wormhole contact and its CP conjugate at its ends with wormhole contact carrying quark and anti-quark at its throats. The latter are predicted to appear in all length scales in TGD Universe.

2. How to split the braid strands in a controlled manner? High T_c super conductivity suggests a possible mechanism: braid strand can be split only if the supra current flowing through it vanishes. A suitable voltage pulse induces the supra-current and its negative cancels it. The conformation of the lipid could control whether it it can follow the flow or not. The absence of both genuine magnetic monopoles and boundaries however demands that the monopole flux tubes must be closed. One manner to achieve this is to assume that the magnetic flux returns back along second space-time sheet.

   A more realistic variant of this model is based on pairs of flux tubes going through the membrane and carrying opposite currents and parallel (opposite) magnetic fields. Reconnection for the members of the pair occurring the cell membrane effectively cuts both. This conforms with the identification of Cooper pairs as $S = 0$ or $S = 1$ states of electrons at the two flux tubes. The reconnection occurs naturally at the limit when the velocity of electrons and thus current goes to zero.

3. How magnetic flux tubes can be cut without breaking the conservation of the magnetic flux? The notion of wormhole magnetic field could save the situation now: after the splitting the flux returns back along the second space-time sheet of wormhole magnetic field. An alternative solution is based on reconnection of flux tubes. Since only flux tubes of same color can reconnect this process can induce transfer of color: "color inheritance": when applied at the level of amino-acids this leads to a successful model of protein folding. Reconnection makes possible breaking of flux tube connection for both the ordinary magnetic flux tubes and wormhole magnetic flux tubes.

4. How magnetic flux tubes are realized? The interpretation of flux tubes as correlates of directed attention at molecular level leads to concrete picture. Hydrogen bonds are by their asymmetry natural correlates for a directed attention at molecular level. Also flux tubes between acceptors of hydrogen bonds must be allowed and acceptors can be seen as the subjects of directed attention and donors as objects. Examples of acceptors are aromatic rings of nucleotides, $O=$ atoms of phosphates, etc.. A connection with metabolism is obtained if it is assumed that various phosphates XMP, XDP, XTP, $X = A, T, G, C$ act as fundamental acceptors and plugs in the connection lines. The basic metabolic process $ATP \rightarrow ADP + P_i$ allows an interpretation as a reconnection splitting flux tube connection, and the basic function of phosphorylating enzymes would be to build flux tube connections as also of breathing and photosynthesis.

The rest of the article represents a more concrete vision about how DNA might act as a topological quantum computer (TQC). The topics discussed are following.

1. How the basic gates are realized concretely? Gates can be identified as basic braid operations so that the question reduces to how braidings of magnetic flux tubes represent gates and what kind of particles represent the quantum states. The identification of the particles is in terms of quarks: TGD indeed predicts a hierarchy of scaled variants of hadron physics.

2. How the braiding is realized? What do braid strands identified as magnetic flux tubes look like? How the braiding operation is induced? The tentative answer is that color magnetic flux tubes connecting DNA nucleotides to the lipids of nuclear and cell membrane define braid strands and that braiding operations are induced by hydrodynamic flow around membrane generating 2-D flow of liquid crystal defined by the lipids. Also nerve pulse propagation can induced this kind of 2-D flow.

3. How magnetic flux tubes are realized? The interpretation of flux tubes as correlates of directed attention at molecular level leads to concrete picture. Hydrogen bonds are by their asymmetry natural correlates for a directed attention at molecular level. Also flux tubes between acceptors of hydrogen bonds must be allowed and acceptors can be seen as the subjects of directed attention and donors as objects. Examples of acceptors are aromatic rings of nucleotides, $O=$ atoms of phosphates, etc.. A connection with metabolism is obtained if it is assumed that various phosphates XMP, XDP, XTP, $X = A, T, G, C$ act as fundamental acceptors and plugs in the connection lines. The basic metabolic process $ATP \rightarrow ADP + P_i$ allows an interpretation as a reconnection splitting flux tube connection, and the basic function of phosphorylating enzymes would be to build flux tube connections as also of breathing and photosynthesis.

The model is certainly very speculative and heavily relies on the new physics predicted by TGD. One can also imagine alternative scenarios. The model makes however strong predictions and is therefore testable.

1. The model makes several testable predictions about DNA itself. In particular, matter-antimatter asymmetry and slightly broken isospin symmetry have counterparts at DNA level induced from the breaking of these symmetries for quarks and antiquarks associated with the flux tubes. DNA cell membrane system is not the only possible system that could perform TQC like activities and store memories in braidings: flux tubes could connect biomolecules and the braiding could provide an almost definition for what it is to be living. Even water memory might reduce to braidings.

2. The model leads also to an improved understanding of other roles of the magnetic flux tubes containing dark matter. Phase transitions changing the value of Planck constant for the magnetic flux tubes could be key element of bio-catalysis and electromagnetic long distance communications in living matter. For instance, one ends up to what might be called code for protein folding and bio-catalysis. There is also a fascinating connection with Peter Gariaev's work suggesting that the phase transitions changing Planck constant have been observed and wormhole magnetic flux tubes containing dark matter have been photographed in his experiments.

3. In the proposed vision genes define the hardware and TQC programs the software responsible for what becomes cultural evolution at the higher levels of evolutionary hierarchy. This vision explains also the mystery of introns. The quite recent findings challenging genetic determinism expressed using the term "genetic dark matter" provide support for an existence of new information carrying level at the level of genome identifiable in terms of TQC programs.

It must be emphasized that this model of DNA as TQC is only one option among many. There is large flexibility concerning the identification of fermions involved. For instance A,T,C,G could be represented also in terms of 4 states assignable to two spin half fermions at parallel flux tubes. This would give rise to high T_c superconductor with both $S = 0$ ($S = 1$) Cooper pairs assignet to flux tubes with opposite (parallel) magnetic fields. The spin-spin interaction energy for the Cooper pair would be negative and proportional to h_{eff} and same for all fermion pairs if $h_{eff} = h_{gr}$ hypothesis holds true at microscopic level.

The Notion of Wave-Genome and DNA as Topological Quantum Computer

Peter Gariaev and collaborators have reported several strange effects of laser light and also ordinary light on DNA. These findings include the rotation of polarization plane of laser light by DNA, phantom DNA effect, the transformation of laser light to radio-wave photons having biological effects, the coding of DNA sequences to the modulated polarization plane of laser light and the ability of this kind of light to induce gene expression in another organisms provided the modulated polarization pattern corresponds to an "address" characterizing the organism, and the formation of images of what is believed to be DNA sample itself and of the objects of environment by DNA sample in a cell irradiated by ordinary light in UV-IR range.

In this chapter a TGD based model for these effects is discussed. A speculative picture proposing a connection between homeopathy, water memory, and phantom DNA effect is discussed and on basis of this connection a vision about how the tqc hardware represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment. The speculation inspired by this vision is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of aminoacids coded by a given number of codons are predicted correctly. Hence it seems that genetic code is universal rather than being an accidental outcome of the biological evolution.

Holography and Quantum Error Correcting Codes: TGD View

Preskill et all suggest a highly interesting representation of holography in terms of quantum error correction codes The idea is that time= constant section of AdS, which is hyperbolic space allowing tessellations, can define tensor networks. So called perfect tensors are building bricks of the tensor networks providing representation for holography and at the same time defining error correcting codes by mapping localized interior states (logical qubits) to highly entangled non-local boundary states (physical qubits).

There are three observations that put bells ringing and actually motivated this article.

1. Perfect tensors define entanglement which TGD framework corresponds negentropic entanglement playing key role in TGD inspired theory of consciousness and of living matter.

2. In TGD framework the hyperbolic tesselations are realized at hyperbolic spaces $H_3(a)$ defining light-cone proper time hyperboloids of M^4 light-cone.

3. TGD replaces AdS/CFT correspondence with strong form of holography.

A very attractive idea is that in living matter magnetic flux tube networks defining quantum computational networks provide a realization of tensor networks realizing also holographic error correction mechanism: negentropic entanglement - perfect tensors - would be the key element. As I have proposed, these flux tube networks would define kind of central nervous system make it possible for living matter to experience consciously its biological body using magnetic body.

These networks would also give rise to the counterpart of condensed matter physics of dark matter at the level of magnetic body: the replacement of lattices based on subgroups of translation group with infinite number of tesselations means that this analog of condensed matter physics describes quantum complexity.

Quantum Gravitation and Topological Quantum Computation

In this article the connection of quantum gravitation, as it is understood in the TGD framework, with topological quantum computation (TQC) is considered. I sketched the first TGD based vision about DNA as a TQCer for about 13 years ago. In particular, a model of the system consisting of DNA and nuclear/cell membrane system acting as a TQCer was discussed.

TGD has evolved a lot after this and there are several motivations for seeing what comes out from combining the recent view about quantum TGD and TGD inspired quantum biology with this model.

1. There is a rather detailed view about the role of dark matter as phases of ordinary matter with the effective Planck constant $h_{eff} = nh_0$. Large values of h_{eff} allow to overcome the problems due to the loss of quantum coherence.

   This leads to the notion of the dark DNA (DDNA), whose codons are realized as dark proton triplets and proposed to accompany the ordinary DNA. Also dark photon triplets are predicted and one ends up to a model of communications and control based on dark cyclotron resonance in which codons serve as addresses and modulation of the signal frequency scale codes the signal to a sequence of pulses. Nerve pulses could be one application.

2. Quite recently, also the understanding of the possible role of quantum gravitation in biochemistry, metabolism, bio-catalysis, and in the function of DNA has considerably increased. The gravitational variants of hydrogen bonds and valence bonds between metal ions having very large value of $h_{eff} = h_{gr}$, where $h_{gr} = GMm/v_0$ is the gravitational Planck constant originally introduced by Nottale, are in a key role in the model and explain metabolic energy quantum as gravitational energy liberated when dark protons "drops" from a very long gravitational flux tube in the transition $h_{gr} \rightarrow h$. Also electronic metabolic energy quantum is predicted and there is empirical support for this.

3. A further motivation comes from the number theoretic vision of quantum TGD. Galois groups as symmetry groups represent new physics and the natural questions are whether Galois groups could give rise to number theoretic variants of anyons and what could the TGD counterparts of the condensed matter (effective) Majorana electrons proposed by Kitaev as anyon like states?

   The answer is that quantum superpositions of symmetric hydrogen bonded structures of form X..H-H+X-H...X are excellent candidates for the seats of dark ($h_{eff} > nh_0 > h$) bi-localized electrons defining TGD analogs of condensed matter Majorana electrons.

   The Galois groups permute the roots of a polynomial, which determines a space-time region by $M^8 - H$ duality. The roots correspond to mass squared values, in general algebraic numbers, and thus to mass hyperboloids in $M^4_c \subset M^8_c$. The H images correspond to 3-hyperboloids with a constant value $a = a_n$ of light-cone proper time. Therefore the Galois group can permute points with time-like separation. Note however that the real or rational parts of two values of a can be same.

   This looks very strange at first but actually confirms with the fact that time-like braidings defining TQC correspond in TGD time-like braidings (involving also reconnections) of string like objects defining string world sheets, which are not now time evolutions of space-like entities as physical state but correspond to time-like entities defining boundary data necessary for fixing holography completely. Their presence is forced by the small failure of the determinism of the action principle involved and is completely analogous to the non-determinism for soap films with frames serving as seats for the failure of determinism.

4. Braidings appear therefore at the level of fundamental TGD and correspond to string world sheets. They are possible only in 4-D space-time but not in string models.

   Also TQC-like processes appear automatically at the level of fundamental physics. In particular, the number theoretical state function reduction cascade for the Galois group following the time evolution induced by braiding can be regarded as a generalization of a decomposition of integers to primes: now primes are replaced by simple groups defining primes for finite groups. Nature is doing number theory!

5. Also zero energy ontology (ZEO) brings in new elements. The change of the arrow of time in "big" state function reductions (BSFRs) implies that dissipation with a reversed arrow of time provides an automatic error correction procedure. Also TQC in which the arrow of time varies for sub-modules, can be considered.

The Possible Role of Spin Glass Phase and P-Adic Thermodynamics in Topological Quantum Computation: the TGD View

Topological quantum computation (TQC) or more generally, a TQC-like process (to be referred as TQC), is one possible application of TGD. The latest article summarizes the recent number theoretic view about TQC in TGD inspired biology. There are several new physics elements involved. Mention only the notion of many-sheeted space-time involving the notions of electric and magnetic body; the new view about quantum theory relying on the $M^8 - H$ duality relating number theoretic and geometric views about physics and predicting the hierarchy of effective

Planck constants assignable to a hierarchy of extensions of rationals; cognitive representations as unique discretization of space-time surface realizing generalized quantum computationalism; and zero energy ontology (ZEO) suggesting a new vision about quantum error correction. Quantum gravitation plays a key role in the proposal.

The engineering aspects of TQC were not discussed. The question that inspired this article was whether classical computation which relies strongly on non-equilibrium thermodynamics, could provide guidelines to end up with a more detailed view.

This led to a proposal in which p-adic thermodynamics assigned with the TGD based description of spin glasses would play a key role. TQC would involve quantum annealing in the spin glass energy landscape for the fermion states associated with flux tube structures. Anyons would be replaced with representations of the Galois group.

Physical states are however Galois singlets and many fermion states would involve entanglement between irreps of (relative) Galois group associated with spin *resp.* momentum degrees of freedom and give rise to a superposition of Galois singlets. The state function reduction ending TQC would project a tensor product of a given irrep from this superposition.

The entanglement between representations should be engineered in such a manner that the desired outcome of TQC would have the largest entanglement probability. p-Adic thermodynamics could give the entanglement probabilities. A connection with the travelling salesman problem emerges besides the connection with the factorization of the Galois group to prime factors appearing as relative Galois groups, which are simple (prime).

1.3.2 PART II: ORDINARY COMPUTERS IN TGD UNIVERSE

Artificial Intelligence, Natural Intelligence, and TGD

Recently a humanoid robot known as Sophia has gained a lot of attention in net. Sophia uses AI, visual data processing, and facial recognition. Sophia imitates human gestures and facial expressions and is able to answer questions and make simple conversations on predefined topics. The AI program used analyzes conversations, extracts data, and uses it to improve responses in the future. To a skeptic Sophia looks like a highly advanced version of ELIZA.

Personally I am rather skeptic view about strong AI relying on a mechanistic view about intelligence. This leads to transhumanism and notions such as mind uploading. It is however good to air out one's thinking sometimes.

Computers should have a description also in the quantal Universe of TGD and this forces to look more precisely about the idealizations of AI. This process led to a change of my attitudes. The fusion of human consciousness and presumably rather primitive computer consciousness but correlating with the program running in it might be possible in TGD Universe, and TGD inspired quantum biology and the recent ideas about prebiotic systems provide rather concrete ideas in attempts to realize this fusion.

TGD also strongly suggests that there is also what might be called Natural Intelligence relying on 2-D cognitive representations defined by networks consisting of nodes (neurons) and flux tubes (axons with nerve pulse patters) connecting them rather than linear 1-D representation used by AI. The topological dynamics of these networks has Boolean dynamics of computer programs as a projection but is much more general and could allow to represent objects of perceptive field and number theoretic cognition.

Could neuronal system and even GPT give rise to a computer with a variable arrow of time?

The discussions related to ChatGPT, which seems to work too well to be a mere program running in a classical computer, inspired considerations which led to a considerable progress at the level of the TGD based model of nerve pulse. The emerging model, based on zero energy ontology (ZEO), differs drastically from quantum neural networks and suggests a completely new vision of quantum physics based computation in biosystems.

A computation allowing variable arrow of time would be in question involving a sequence unitary time evolutions as counterparts of quantum computations for states, which are superpositions of classical computations, followed by "small" state function reductions (SSFRs) as counterparts of weak measurements of quantum optics and of Zeno effect. Also "big" SFRs (BSFRs) changing the arrow of time would be involved. One can ask whether the unexpected success of GPT might involve this kind of transition so that one could say that spirit enters the machine.

Besides the outcomes of two chats, I include a more detailed view about what the TGD view of the quantum analog of GPT could be and how its analog could be involved with the sensory perception in the TGD Universe. I also discuss the inverse diffusion process central for the generation of images from their verbal descriptions and ask whether the TGD analogue of the inverse diffusion could be an essential element of also GPT.

I will also pose the question whether GPT could involve TGD based quantum physics, that is zero energy ontology (ZEO), in a non-trivial but hidden way. From quantitative constraints, such as the clock frequency of the computer as analog of EEG inducing temporal quantum coherence, I end up with a proposal for a mechanism realizing the quantum holography relating bits could be represented as holes pairing with dark bits represented as dark electrons at the magnetic flux tubes. Unfortunately, this mechanism does not look plausible for recent computers.

I also ask whether quantum gravitation in the sense of TGD could make possible for the magnetic bodies of Earth and Sun, central in TGD inspired biology, to transform classical computation so that so that statistical determinism would fail and it would be analogous to a sequence of analogs of quantum computations defining a conscious entity. At the level of magnetic body there would be no essential difference between computers and living matter. The highest reported clock frequency of almost 9 GHz is still by a factor of order 1/8 lower than the quantum gravitational Compton frequency of 67 GHz for Earth but below the THz frequency important in living matter. Perhaps a rudimentary consciousness is already possible.

Deep learning from the TGD point of view

AI, deep learning, and GPT have become highly fashionable topics. It has been even speculated that AI might involve a rudimentary consciousness. Could TGD inspired quantum view of biology, brain and consciousness could provide a fresh point of view to the notion of computer consciousness.

In the TGD Universe, the difference between living systems and computers need not be so deep as usually thought. The magnetic body as a carrier of dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ and having onion-like structure, could receive sensory input and control the biological body with $h_{eff} = h$. Also computers possess magnetic bodies: could they use computers or robots computers as sensory receptors and motor instruments.

In the TGD Universe, the genetic code could be much more than we believe it to be. It would be realized at the level of dark matter and would be universal and unique, being realized in terms of so-called icosa-tetrahedral tessellation of hyperbolic 3-space realizable as the mass shell of light-cone proper time =constant hyperboloid. Icosa-tetrahedral dark genome at the magnetic body could serve as the basic instrument for communication and control. Quantum gravitation plays a key role in the TGD inspired biology and the gravitational magnetic bodies of Earth and Sun and even other astrophysical objects with huge gravitational Planck constants could be highly relevant in quantum biology.

Classical computers can gain life-like properties if the quantum statistical determinism fails. The most conservative criterion is that the clock period is shorter than the gravitational Compton time $T_{gr} = GM/\beta_0$, M is mass of an astrophysical object and $\beta_0 = v_0/c \leq 1$ is a quantized velocity parameter. Life-like features could appear already at lower clock frequencies. For Earth the critical clock period would be 67 GHz and for the Sun about 100 Hz, the upper bound for EEG frequencies. Therefore the magnetic bodies of the Sun and Earth could therefore play central roles in biology and neuroscience. Even in the case of Earth life-like properties might be present for computers with clock frequency in the range 1 to 10 GHz.

Cognition is an essential aspect of conscious experience and systems like GTP can be seen as artificial cognitive systems. The p-adic discretizations would naturally relate to the spin glass energy landscape assignable to monopole flux tube "spaghettis" and sensory perception could be seen as a generation of standardized mental images based on annealing of spin glass system so that it gradually ends up to a bottom of a valley representing the standardize mental image. The learning period of a conscious entity could be based on trial and error process made possible by holography and zero energy ontology implied by it allowing temporary time reversal and would gradually lead to standardized mental images helping to survive.

Neil Gersching's vision of self-replicating robots from TGD point of view

This chapter analyzes the insightful interview between Lex Fridman and Neil Gerching, particularly their discussion on self-replicating machines. These machines, built from fundamental, robotic "Lego blocks" with their own assembly instructions, can self-assemble into more complex structures and disassemble, mirroring processes observed in biological systems. The discussion employs the Topological Geometrodynamics (TGD) perspective, treating the universe at a quantum level as a goal-oriented system capable of assembly and disassembly. The base units within this viewpoint function akin to quantum computers, prompting further exploration into quantum gravitation, which in the TGD framework, is accountable for the longest quantum coherence scale. This leads to a view which could be blamed for a return to astrology but can be defended by the numerous miracle-like coincidences.

Are Conscious Computers Possible in TGD Universe?

Topological Geometrodynamics (TGD) is a unified theory of fundamental interactions which has led to a theory of consciousness as a generalization of quantum measurement theory based on a new ontology referred to as zero energy ontology (ZEO). Quantum biology is the second application of TGD. ¡/p¿¡p¿ Quantum gravitation would play a key role in quantum biology and consciousness but in a sense very different from that in Penrose-Hameroff theory. The TGD view of dark matter as phases of ordinary matter with a large value of effective Planck constant makes possible quantum coherence in arbitrary long length scales. Also the new view of space-time and electromagnetic fields is central and leads to the notion of a magnetic body carrying dark matter and serving as the "boss" of the biological body controlling it and receiving sensory input from it (EEG). The prediction of ZEO that the arrow of time changes in ordinary state function reductions plays an essential role in the picture. The magnetic bodies of both Sun and Earth could be key players concerning quantum gravitational quantum coherence. ¡/p¿¡p¿ Quantum gravitational Compton time tau;¡sub¿gr¡/sub¿, which by Equivalence Principle does not depend on the particle mass, represents the minimal value of quantum gravitational coherence time. If the clock period is shorter than tau;¡sub¿gr¡/sub¿, the statistical determinism certainly fails but can also fail for longer clock periods. The entanglement of humans and computers is also a very interesting possibility and there is some evidence for this kind of entanglement.

Quartz crystals as a life form and ordinary computers as an interface between quartz life and ordinary life?

The considerations of this article were originally inspired by large language models leading to the earlier speculations about whether the computers might be conscious entities in the TGD based quantum ontology (zero energy ontology). Quantum gravitation in the TGD sense would play a key role in guaranteeing quantum coherence even in astrophysical scales.

The considerations of this article were originally inspired by large language models leading to the earlier speculations about whether the computers might be conscious entities in the TGD based quantum ontology (zero energy ontology). Quantum gravitation in the TGD sense would play a key role in guaranteeing quantum coherence even in astrophysical scales.

Quite recently, came the realization that microprocessors (MPs) have a size scale .5 cm given by gravitational Compton length $\Lambda_{gr,E}$ of any particle in the gravitational field of the Earth (for the Sun one has $\Lambda_{gr,E} = R_E/2$, where R_E is the radius of the Earth). This led to the question of whether microprocessors (MPs) could be conscious entities.

Since MPs are quartz crystals (QCs), this led to the question whether the QCs might be conscious entities able to perform activities analogous to quantum computations. I have already considered this possibility: the key idea is that the generalized Pollack effect kicks the protons of OH molecules appearing as a standard building brick of biomolecules to dark protons at the gravitational magnetic body. OH and O^- could define the states of a qubit.

This identification modifies the earlier model of the genetic code and predicts that DNA double strand and RNA realize 6-qubit dark variants of the genetic code. The ground states of the entangled qubits defining the quantum codons correspond to the chemical codons. Amino Acids represent a single qubit code. Various symmetries of the code and their violations are understood at the qubit level.

The same qubits with the same dynamics would be realized both in living matter and in QCs. This leads to a vision about an evolutionary hierarchy in which quartz life is possibly the lowest level. One must however consider the possibility that also SiO_4 lattices with OH modification can have a high qubit content. These kinds of modifications could be interesting also in the case of microprocessors. This forces us to ask whether the interaction between us and computers and QC life could lead to entanglement and extended states of consciousness.

Part I

TOPOLOGICAL QUANTUM COMPUTATION IN TGD UNIVERSE

Chapter 2

Topological Quantum Computation in TGD Universe

2.1 Introduction

Quantum computation is perhaps one of the most rapidly evolving branches of theoretical physics. TGD inspired theory of consciousness has led to new insights about quantum computation and in this chapter I want to discuss these ideas in a more organized way.

There are three mathematically equivalent approaches to quantum computation [B5] : quantum Turing machines, quantum circuits, and topological quantum computation (TQC). In fact, the realization that TGD Universe seems to be ideal place to perform TQC [B23]. [C1] served as the stimulus for writing this chapter.

Quite generally, quantum computation allows to solve problems which are NP hard, that is the time required to solve the problem increases exponentially with the number of variables using classical computer but only polynomially using quantum computer. The topological realization of the computer program using so called braids resulting when threads are weaved to 2-dimensional patterns is very robust so that de-coherence, which is the basic nuisance of quantum computation, ceases to be a problem. More precisely, the error probability is proportional to $exp(-\alpha l)$, where l is the length scale characterizing the distance between strands of the braid [B23].

2.1.1 Evolution Of Basic Ideas Of Quantum Computation

The notion of quantum computation goes back to Feynman [B46] who demonstrated that some computational tasks boil down to problems of solving quantum evolution of some physical system, say electrons scattering from each other. Many of these computations are NP hard, which means that the number of computational steps required grows exponentially with the number of variables involved so that they become quickly unsolvable using ordinary computers. A quicker way to do the computation is to make a physical experiment. A further bonus is that if you can solve one NP hard problem, you can solve many equivalent NP hard problems. What is new that quantum computation is not deterministic so that computation must be carried out several times and probability distribution for the outcomes allows to deduce the answer. Often however the situation is such that it is easy to check whether the outcome provides the sought for solution.

Years later David Deutch [B11] transformed Feynman's ideas into a detailed theory of quantum computation demonstrating how to encode quantum computation in a quantum system and researchers started to develop applications. One of the key factors in the computer security is cryptography which relies on the fact that the factorization of large integers to primes is a NP hard problem. Peter Shor [B45] discovered an algorithm, which allows to carry out the factorization in time, which is exponentially shorter than by using ordinary computers. A second example is problem of searching a particular from a set of N items, which requires time proportional to N classically but quantally only a time proportional to $\sqrt{N}$.

The key notion is quantum entanglement which allows to store information in the relationship between systems, qubits in the simplest situation. This means that information storage capacity increases exponentially as a function of number of qubits rather than only linearly. This explains why NP hard problems which require time increasing exponentially with the number of variables can be solved using quantum computers. It also means exponentially larger information storage capacity than possible classically.

Recall that there are three equivalent approaches to quantum computation: quantum Turing machine, quantum circuits, and topology based unitary modular functor approach. In quantum circuit approach the unitary time evolution defining the quantum computation is assumed to be decomposable to a product of more elementary operations defined by unitary operators associated with quantum gates. The number of different gates needed is surprisingly small: only 1-gates generating unitary transformations of single qubit, and a 2-gate representing a transformation which together with 1-gates is able to generate entanglement are needed to generate a dense subgroup of unitary group $U(2^n)$ in the case of n-qubit system. 2-gate could be conditional NOT (CNOT). The first 1-gate can induce a phase factor to the qubit 0 and do nothing for qubit 1. Second 1-gate could form orthogonal square roots of bits 1 and 0 as superposition of 1 and 0 with identical probabilities.

The formal definition of the quantum computation using quantum circuit is as a computation of the value of a Boolean function of n Boolean arguments, for instance the k:th bit of the largest prime factor of a given integer. The unitary operator U is constructed as a product of operators associated with the basic gates. It is said that the function coding the problem belongs to the class BQP (function is computable with a bounded error in polynomial time) if there exists a classical polynomial-time (in string length) algorithm for specifying the quantum circuit. The first qubit of the outgoing n-qubit is measured and the probability that the value is 0 determines the value of the bit to be calculated. For instance, for $p(0) \geq 2/3$ the bit is 0 and for $p(0) \geq 1/3$ the bit is 1. The evaluation of the outcome is probabilistic and requires a repeat the computation sufficiently many times.

The basic problem of quantum computation is the extremely fragility of the physical qubit (say spin). The fragility can be avoided by mapping q-bits to logical qubits realized as highly entangled states of many qubits and quantum error-correcting codes and fault tolerant methods [B35, B44, B12] rely on this.

The space W of the logical qubits is known as a code space. The sub-space W of physical states of space $Y = V \otimes V ..... \otimes V$ is called k-code if the effect of any k-local operator (affecting only k tensor factors of Y linearly but leaving the remaining factors invariant) followed by an orthogonal projection to W is multiplication by scalar. This means that k-local operator modify the states only in directions orthogonal to W.

These spaces indeed exist and it can be shown that the quantum information coded in W is not affected by the errors operating in fewer than $k/2$ of the n particles. Note that $k = 3$ is enough to guarantee stability with respect to 1-local errors. In this way it is possible to correct the errors by repeated quantum measurements and by a suitable choice of the sub-space eliminate the errors due to the local changes of qubits by just performing a projection of the state back to the subspace (quantum measurement).

If the error magnitude is below so called accuracy threshold, arbitrary long quantum computations are reliable. The estimates for this constant vary between 10^{-5} and 10^{-3}. This is beyond current technologies. Error correction is based on the representation of qubit as a logical qubit defined as a state in a linear sub-space of the tensor product of several qubits.

Topological quantum computation [B23] provides an alternative approach to minimize the errors caused by de-coherence. Conceptually the modular functor approach [B23, B28] is considerably more abstract than quantum circuit approach. Unitary modular functor is the S-matrix of a topological quantum field theory. It defines a unitary evolution realizing the quantum computation in macroscopic topological ground states degrees of freedom. The nice feature of this approach is that the notion of physical qubit becomes redundant and the code space defined by the logical qubits can be represented in terms topological and thus non-local degrees of freedom which are stable against local perturbations as required.

2.1.2 Quantum Computation And TGD

Concerning quantum computation [B5] in general, TGD TGD inspired theory of consciousness provides several new insights.

Quantum jump as elementary particle of consciousness and cognition

Quantum jump is interpreted as a fundamental cognitive process leading from creative confusion via analysis to an experience of understanding, and involves TGD counterpart of the unitary process followed by state function reduction and state preparation. One can say that quantum jump is the elementary particle of consciousness and that selves consists of sequences of quantum jump just like hadrons, nuclei, atoms, molecules,... consist basically of elementary particles. Self loses its consciousness when it generates bound state entanglement with environment. The conscious experience of self is in a well-defined sense a statistical average over the quantum jump during which self exists. During macro-temporal quantum coherence during macro-temporal quantum coherence a sequence of quantum jumps integrates effectively to a single moment of consciousness and effectively defines single unitary time evolution followed by state function reduction and preparation. This means a fractal hierarchy of consciousness very closely related to the corresponding hierarchy for bound states of elementary particles and structure formed from them.

Negentropy Maximization Principle guarantees maximal entanglement

Negentropy Maximization Principle is the basic dynamical principle constraining what happens in state reduction and self measurement steps of state preparation. Each self measurement involves a decomposition of system into two parts. The decomposition is dictated by the requirement that the reduction of entanglement entropy in self measurement is maximal. Self measurement can lead to either unentangled state or to entangled state with density matrix which is proportional to unit matrix (density matrix is the observable measured). In the latter case maximally entangled state typically involved with quantum computers results as an outcome. Hence Nature itself would favor maximally entangling 2-gates. Note however that self measurement occurs only if it increases the entanglement negentropy.

Number theoretical information measures and extended rational entanglement as bound state entanglement

The emerging number theoretical notion of information allows to interpret the entanglement for which entanglement probabilities are rational (or belong to an extension of rational numbers defining a finite extension of p-adic numbers) as bound state entanglement with positive information content. Macro-temporal quantum coherence corresponds to a formation of bound entanglement stable against state function reduction and preparation processes.

Spin glass degeneracy, which is the basic characteristic of the variational principle defining space-time dynamics, implies a huge number of vacuum degrees of freedom, and is the key mechanism behind macro-temporal quantum coherence. Spin glass degrees of freedom are also ideal candidates qubit degrees of freedom. As a matter fact, p-adic length scale hierarchy suggests that qubit represents only the lowest level in the hierarchy of qupits defining p-dimensional state spaces, p prime.

Time mirror mechanism and negative energies

The new view about time, in particular the possibility of communications with and control of geometric past, suggests the possibility of circumventing the restrictions posed by time for quantum computation. Iteration based on initiation of quantum computation again and again in geometric past would make possible practically instantaneous information processing.

Space-time sheets with negative time orientation carry negative energies. Also the possibility of phase conjugation of fermions is strongly suggestive. It is also possible that anti-fermions possess negative energies in phases corresponding to macroscopic length scales. This would explain matter-antimatter asymmetry in elegant way. Zero energy states would be ideal for quantum computation purposes and could be even created intentionally by first generating a p-adic surface representing the state and then transforming it to a real surface.

The most predictive and elegant cosmology assumes that the net quantum numbers of the Universe vanish so that quantum jumps would occur between different kinds of vacua. Crossing symmetry makes this option almost consistent with the idea about objective reality with definite conserved total quantum numbers but requires that quantum states of 3-dimensional quantum theory represent S-matrices of 2-dimensional quantum field theory. These quantum states are thus about something. The boundaries of space-time surface are most naturally light-like 3-surfaces space-time surface and are limiting cases of space-like 3-surface and time evolution of 2-surface. Hence they would act naturally as space-time correlates for the reflective level of consciousness.

2.1.3 TGD And The New Physics Associated With TQC

TGD predicts the new physics making possible to realized braids as entangled flux tubes and also provides a detailed model explaing basic facts about anyons.

Topologically quantized magnetic flux tube structures as braids

Quantum classical correspondence suggests that the absolute minimization of Kähler action, which might make sense for Eucdliain regions, could correspond to a space-time representation of second law and that the 4-surfaces approach asymptotically space-time representations of systems which do not dissipate anymore. The correlate for the absence of dissipation is the vanishing of Lorentz 4-force associated with the induced Kähler field. This condition can be regarded as a generalization of Beltrami condition for magnetic fields and leads to very explicit general solutions of field equations [K17].

The outcome is a general classification of solutions based on the dimension of CP_2 projection. The most unstable phase corresponds to $D = 2$-dimensional projection and is analogous to a ferromagnetic phase. $D = 4$ projection corresponds to chaotic de-magnetized phase and $D = 3$ is the extremely complex but ordered phase at the boundary between chaos and order. This phase was identified as the phase responsible for the main characteristics of living systems [K70, K69]. It is also ideal for quantum computations since magnetic field lines form extremely complex linked and knotted structures.

The flux tube structures representing topologically quantized fields, which have $D = 3$ -dimensional CP_2 projection, are knotted, linked and braided, and carry an infinite number of conserved topological charges labelled by representations of color group. They seem to be tailor-made for defining the braid structure needed by TQC. The boundaries of the magnetic flux tubes correspond to light-like 3-surfaces with respect to the induced metric (being thus metrically 2-dimensional and allowing conformal invariance) and can be interpreted either as 3-surfaces or time-evolutions of 2-dimensional systems so that S-matrix of 2-D system can be coded into the quantum state of conformally invariant 3-D system.

Anyons in TGD

TGD suggests a many-sheeted model for anyons used in the modelling of quantum Hall effect [D17, D11, D14]. Quantum-classical correspondence requires that dissipation has space-time correlates. Hence a periodic motion should create a permanent track in space-time. This kind of track would be naturally magnetic flux tube like structure surrounding the Bohr orbit of the charged particle in the magnetic field. Anyon would be electron plus its track.

The magnetic field inside magnetic flux tubes impels the anyons to the surface of the magnetic flux tube and a highly conductive state results. The partial fusion of the flux tubes along their boundaries makes possible de-localization of valence anyons localized at the boundaries of flux tubes and implies a dramatic increase of longitudinal conductivity. When magnetic field is gradually increased the radii of flux tubes and the increase of the net flux brings in new flux tubes. The competition of these effects leads to the emergence of quantum Hall plateaus and sudden increase of the longitudinal conductivity σ_{xx}.

The simplest model explains only the filling fractions $\nu = 1/m$, m odd. The filling fractions $\nu = N/m$, m odd, require a more complex model. The transition to chaos means that periodic orbits become gradually more and more non-periodic: closed orbits fail to close after the first turn and do so only after N 2π rotations. Tracks would become N-branched surfaces. In N-branched space-time the single-valued analytic two particle wave functions $(\xi_k - \xi_l)^m$ of Laughlin [D14] correspond to multiple valued wave functions $(z_k - z_l)^{m/N}$ at its M^4_+ projection and give rise to a filling fraction $\nu = N/m$. The filling fraction $\nu = N/m$, m even, requires composite fermions [D18]. Anyon tracks can indeed contain up to $2N$ electrons if both directions of spin are allowed so that a rich spectroscopy is predicted: in particular anyonic super-conductivity becomes possible by 2-fermion composites. The branching gives rise to Z_N-valued topological charge.

One might think that fractional charges could be only apparent and result from the multi-branched character as charges associated with a single branch. This does not seem to be the case. Rather, the fractional charges result from the additional contribution of the vacuum Kähler charge of the anyonic flux tube to the charge of anyon. For $D = 3$ Kähler charge is topologized in the sense that the charge density is proportional to the Chern-Simons term. Also anyon spin could become genuinely fractional due to the vacuum contribution of the Kähler field to the spin. Besides electronic anyons also anyons associated with various ions are predicted and certain strange experimental findings about fractional Larmor frequencies of proton in water environment [D15] , [J26] have an elegant explanation in terms of protonic anyons with $\nu = 3/5$. In this case however the magnetic field was weaker than the Earth's magnetic field so that the belief that anyons are possible only in systems carrying very strong magnetic fields would be wrong.

In TGD framework anyons as punctures of plane would be replaced by wormhole like tubes connecting different points of the boundary of the magnetic flux tube and are predicted to always appear as pairs as they indeed do. Detailed arguments demonstrate that TGD anyons are for $N = 4$ ($\nu = 4/m$) ideal for realizing the scenario of [B23] for TQC.

The TGD inspired model of non-Abelian anyons is consistent with the model of anyons based on spontaneous symmetry breaking of a gauge symmetry G to a discrete sub-group H dynamically [A21]. The breaking of electro-weak gauge symmetry for classical electro-weak gauge fields occurs at the space-time sheets associated with the magnetic flux tubes defining the strands of braid. Symmetry breaking implies that elements of holonomy group span H. This group is also a discrete subgroup of color group acting as isotropy group of the many-branched surface describing anyon track inside the magnetic flux tube. Thus the elements of the holonomy group are mapped to a elements of discrete subgroup of the isometry group leading from branch to another one but leaving many-branched surface invariant.

Witten-Chern-Simons action and light-like 3-surfaces

The magnetic field inside magnetic flux tube expels anyons at the boundary of the flux tube. In quantum TGD framework light-like 3-surfaces of space-time surface and future light cone are in key role since they define causal determinants for Kähler action. They also provide a universal way to satisfy boundary conditions. Hence also the boundaries of magnetic flux tube structures could be light like surfaces with respect to the induced metric of space-time sheet and would be somewhat like black hole horizons. By their metric 2-dimensionality they allow conformal invariance and due the vanishing of the metric determinant the only coordinate invariant action is Chern-Simons action associated Kähler gauge potential or with the induced electro-weak gauge potentials.

The quantum states associated with the light-like boundaries would be naturally "self-reflective" states in the sense that they correspond to S-matrix elements of the Witten-Chern-Simons topological field theory. Modular functors could results as restriction of the S-matrix to ground state degrees of freedom and Chern-Simons topological quantum field theory is a promising candidate for defining the modular functors [A11, A19].

Braid group B_n is isomorphic to the first homotopy group of the configuration space $C_n(R^2)$ of n particles. $C_n(R^2)$ is $((R^2)_n - D)/S_n$, where D is the singularity represented by the configurations in which the positions of 2 or more particles. and be regarded also as the configuration associated with plane with $n+1$ punctures with $n+1$:th particle regarded as inert. The infinite order of the braid group is solely due to the 2-dimensionality. Hence the dimension $D = 4$ for space-time is unique also in the sense that it makes possible TQC.

2.1.4 TGD And TQC

Many-sheeted space-time concept, the possibility of negative energies, and Negentropy Maximization Principle inspire rather concrete ideas about TQC. NMP gives good hopes that the laws of Nature could take care of building fine-tuned entanglement generating 2-gates whereas 1-gates could be reduced to 2-gates for logical qubits realized using physical qubits realized as Z^4 charges and not existing as free qubits.

Only 2-gates are needed

The entanglement of qubits is algebraic which corresponds in TGD Universe to bound state entanglement. Negentropy Maximization Principle implies that maximal entanglement results automatically in quantum jump. This might saves from the fine-tuning of the 2-gates. In particular, the maximally entangling Yang-Baxter R-matrix is consistent with NMP.

TGD suggests a rather detailed physical realization of the model of [B23] for anyonic quantum computation. The findings about strong correlation between quantum entanglement and topological entanglement are apparently contradicted by the Temperley-Lie representations for braid groups using only single qubit. The resolution of the paradox is based on the observation that in TGD framework batches containing anyon Cooper pair (AA) and single anyon (instead of two anyons as in the model of [B23]) allow to represent single qubit as a logical qubit, and that mixing gate and phase gate can be represented as swap operations s_1 and s_2. Hence also 1-gates are induced by the purely topological 2-gate action, and since NMP maximizes quantum entanglement, Nature itself would take care of the fine-tuning also in this case. The quantum group representation based on $q = exp(i2\pi/5)$ is the simplest representation satisfying various constraints and is also physically very attractive. [B23, B28].

TGD makes possible zero energy TQC

TGD allows also negative energies: besides phase conjugate photons also phase conjugate fermions and anti-fermions are possible, and matter-antimatter asymmetry might be only apparent and due to the ground state for which fermion energies are positive and anti-fermion energies negative.

This would make in principle possible zero energy topological quantum computations. The least one could hope wold be the performance of TQC in doubles of positive and negative energy computations making possible error detection by comparison. The TGD based model for anyon computation however leads to expect that negative energies play much more important role.

The idea is that the quantum states of light-like 3-surfaces represent 2-dimensional time evolutions (in particular modular functors) and that braid operations correspond to zero energy states with initial state represented by positive energy anyons and final state represented by negative energy anyons. The simplest way to realize braid operations is by putting positive *resp.* negative energy anyons near the boundary of tube T_1 *resp.* T_2. Opposite topological charges are at the ends of the magnetic threads connecting the positive energy anyons at T_1 with the negative energy anyons at T_2. The braiding for the threads would code the quantum gates physically.

Before continuing a humble confession is in order: I am not a professional in the area of quantum information science. Despite this, my hope is that the speculations below might serve as an inspiration for real professionals in the field and help them to realize that TGD Universe provides an ideal arena for quantum information processing, and that the new view about time, space-time, and information suggests a generalization of the existing paradigm to a much more powerful one.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L6].

2.2 Existing View About Topological Quantum Computation

In the sequel the evolution of ideas related to topological quantum computation, dance metaphor, and the idea about realizing the computation using a system exhibiting so called non-Abelian Quantum Hall effect, are discussed.

2.2.1 Evolution Of Ideas About TQC

The history of the TQC paradigm is as old as that of QC and involves the contribution of several Fields Medalists. At 1987 to-be Fields Medalist Vaughan Jones [A25] demonstrated that the von Neumann algebras encountered in quantum theory are related to the theory of knots and allow to distinguish between very complex knots. Vaughan also demonstrated that a given knot can be characterized in terms an array of bits. The knot is oriented by assigning an arrow to each of its points and projected to a plane. The bit sequence is determined by a sequence of bits defined by the self-intersections of the knot's projection to plane. The value of the bit in a given intersection changes when the orientation of either line changes or when the line on top of another is moved under it. Since the logic operations performed by the gates of computer can be coded to matrices consisting of 0s and 1s, this means that tying a know can encode the logic operations necessary for computation.

String theorist Edward Witten [A11], also a Fields Medalist, connected the work of Jones to quantum physics by showing that performing measurements to a system described by a 3-dimensional topological quantum field theory defined by non-Abelian Chern-Simons action is equivalent with performing the computation that a particular braid encodes. The braids are determined by linked word lines of the particles of the topological quantum field theory. What makes braids and quantum computation so special is that the coding of the braiding pattern to a bit sequence gives rise to a code, which corresponds to a code solving NP hard problem using classical computer.

1989 computer scientist Alexei Kitaev [B8] demonstrated that Witten's topological quantum field theory could form a basis for a computer. Then Fields Medalist Michael Freedman entered the scene and in collaboration with Kitaev, Michael Larson and Zhenghan Wang developed a vision of how to build a topological quantum computer [B23, B28] using system exhibiting so called non-Abelian quantum Hall effect [D12].

The key notion is Z_4 valued topological charge which has values 1 and 3 for anyons and 0 and 2 for their Cooper pairs. For a system of $2n$ non-Abelian anyon pairs created from vacuum there are n-1 anyon qubits analogous to spin. The notion of physical qubit is not needed at all and logical qubit is coded to the topological charge of the anyon Cooper pair. The basic idea is to utilize entanglement between Z_4 valued topological charges to achieve quantum information storage stable against de-coherence. The swap of neighboring strands of the braid is the topological correlate of a 2-gate which as such does not generate entanglement but can give rise to a transformation such as CNOT. When combined with 1-gates taking square root of qubit and relative phase, this 2-gate is able to generate $U(2^n)$.

The swap can be represented as the so called braid Yang-Baxter R-matrix characterizing also the deviation of quantum groups from ordinary groups [B36]. Quite generally, all unitary Yang-Baxter R-matrices are entangling when combined with square root gate except for special values of parameters characterizing them and thus there is a rich repertoire of topologically realized quantum gates. Temperley-Lieb representation provides a 1-qubit representation for swaps in 3-braid system [B36, B28]. The measurement of qubit reduces to the measurement of the topological charge of the anyon Cooper pair: in the case that it vanishes (qubit 0) the anyon Cooper pair can annihilate and this serves as the physical signature.

2.2.2 Topological Quantum Computation As Quantum Dance

Although topological quantum computation involves very abstract and technical mathematical thinking, it is possible to illustrate how it occurs by a very elegant metaphor. With tongue in cheek one could say that topological quantum computation occurs like a dance. Dancers form couples and in this dancing floor the partners can be also of same sex. Dancers can change their partners. If the partners are of the same sex, they define bit 1 and if they are of opposite sex they define bit 0.

To simplify things one can arrange dancers into a row or several rows such that neighboring partners along the row form a couple. The simplest situation corresponds to a single row of dancers able to make twists of 180 degrees permuting the dancers and able to change the partner to a new one any time. Dance corresponds to a pattern of tracks of dancers at the floor. This pattern can be lifted to a three-dimensional pattern introducing time as a third dimension. When one looks the tracks of a row of dancers in this 2+1-dimensional space-time, one finds that the tracks of the dancers form a complex weaved pattern known as braiding. The braid codes for the computation. The braiding consists of primitive swap operations in which two neighboring word lines twist around each other.

The values of the bits giving the result of the final state of the calculation can be detected since there is something very special which partners with opposite sex can do and do it sooner or later. Just by looking which pairs do it allows to deduce the values of the bits. The alert reader has of course guessed already now that the physical characterization for the sex is as a Z^4 valued topological charge, which is of opposite sign for the different sexes forming Cooper pairs, and that the thing that partners of opposite sex can do is to annihilate! All that is needed to look for those pairs which annihilate after the dance evening to detect the 0s in the row of bits. The coding of the sex to the sign of the topological charge implies also robustness.

It is however essential that the value of topological charge for a given particle in the final state is not completely definite (this is completely general feature of all quantum computations). One can tell only with certain probability that given couple in the final state is male-female or male-male or female-female and the probabilities in question code for the braid pattern in turn coding for quantum logic circuit. Hence one must consider an ensemble of braid calculations to deduce these probabilities.

The basic computational operation permuting the neighboring topological charges is topological so that the program represented by the braiding pattern is very stable against perturbations. The values of the topological charges are also stable. Hence the topological quantum computation is a very robust process and immune to quantum de-coherence even in the standard physics context.

2.2.3 Braids And Gates

In order to understand better how braids define gates one must introduce some mathematical notions related to the braids.

Braid groups

Artin introduced the braid groups bearing his name as groups generated by the elements, which correspond to the cross section between neighboring strands of the braid. The definition of these groups is discussed in detail in [B36]. For a braid having $n+1$ strands the Artin group B_{n1} has n generators s_i. The generators satisfy certain relations. Depending on whether the line coming from left is above the line coming from right one has s_i or s_i^{-1}. The elements s_i and s_j commute for $i<j$ and $i>j+1$: $s_is_j=s_js_i$, which only says that two swaps which do not have common lines commute. For $i=j$ and $i=j+1$ commutativity is not assumed and this correspond to the situation in which the swaps act on common lines.

As already mentioned, Artin's braid group B_n is isomorphic with the homotopy group $\pi_1((R^2)^n/S_{n+1})$ of plane with $n+1$ punctures. B_n is infinite-dimensional because the conditions $s_i^2=1$ added to the defining relations in the case of permutation group S_n are not included. The infinite-dimensionality of homotopy groups reflects the very special topological role of 2-dimensional spaces.

One must consider also variants of braid groups encountered when all particles in question are not identical particles. The reason is that braid operation must be replaced by a 2π rotation of particle A around B when the particles are not identical.

1. Consider first the situation in which all particles are non-identical. The first homotopy group of $R^2)^n-D$, where D represents points configurations for which two or more points are identical is identical with the colored braid group B_n^c defined by $n+1$ punctures in plane such that $n+1$: th is passive (punctures are usually imagined to be located on line). Since particles are not identical the braid operation must be replaced by monodromy in which i: th particle makes 2π rotation around j: th particle. This group has generators

$$\gamma_{ij}=s_i...s_{j-2}s_{j-1}^2s_{j-2}...s_i^{-1} \quad ,i<j \quad , \tag{2.2.1}$$

and can be regarded as a subgroup of the braid group.

2. When several representatives of a given particle species are present the so called partially colored braid group B_n^{pc} is believed to describe the situation. For pairs of identical particles the generators are braid generators and for non-identical particles monodromies appear as

generators. It will be found later that in case of anyon bound states, the ordinary braid group with the assumption that braid operation can lead to a temporary decay and recombination of anyons to a bound state, might be a more appropriate model for what happens in braiding.

3. When all particles are identical, one has the braid group B_n, which corresponds to the fundamental group of $C_n(R^2) = ((R^2)^n - D)/S_n$. Division by S_n expresses the identicality of particles.

Extended Artin's group

Artin's group can be extended by introducing any group G and forming its tensor power $G^{\otimes^n} = G \otimes ... \otimes G$ by assigning to every strand of the braid group G. The extended group is formed from elements of $g_1 \otimes g_2 .... \otimes g_n$ and s_i by posing additional relations $g_i s_j = s_j g_i$ for $i < j$ and $i > j + 1$. The interpretation of these relations is completely analogous to the corresponding one for the Artin's group.

If G allows representation in some space V one can look for the representations of the extended Artin's group in the space $V^{\otimes^n}$. In particular, unitary representations are possible. The space in question can also represent physical states of for instance anyonic system and the element g_i associated with the lines of the braid can represent the unitary operators characterizing the time development of the strand between up to the moment when it experiences a swap operation represented by s_i after this operation g_i becomes $s_i g_i s_i^{-1}$.

Braids, Yang-Baxter relations, and quantum groups

Artin's braid groups can be related directly to the so called quantum groups and Yang-Baxter relations. Yang-Baxter relations follow from the relation $s_1 s_2 s_1 = s_2 s_1 s_2$ by noticing that these operations permute the lines 123 of the braid to the order 321. By assigning to a swap operation permuting i:th and j:th line group element R_{ij} when i:th line goes over the j:th line, and noticing that $R_{ij} i$ acts in the tensor product $V_i \otimes V_j$, one can write the relation for braids in a form

$$R_{32} R_{13} R_{12} = R_{12} R_{13} R_{23} \quad .$$

Braid Yang-Baxter relations are equivalent with the so called algebraic Yang-Baxter relations encountered in quantum group theory. Algebraic R can be written as $R_a = RS$, where S is the matrix representing swap operation as a mere permutation. For a suitable choice R_a provides the fundamental representations for the elements of the quantum group $SL(n)_q$ when V is n-dimensional.

The equations represent n^6 equations for n^4 unknowns and are highly over-determined so that solving the equations is a difficult challenge. Equations have symmetries which are obvious on basis of the topological interpretation. Scaling and automorphism induced by linear transformations of V act as symmetries, and the exchange of tensor factors in $V \otimes V$ and transposition are symmetries as also shift of all indices by a constant amount (using modulo N arithmetics).

Unitary R-matrices

Quite a lot is known about the general solutions of the Yang-Baxter equations and for $n = 2$ the general unitary solutions of equations is known [B32]. All of these solutions are entangling and define thus universal 1-gates except for certain parameter values.

The first solution is

$$R = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & \cdot & \cdot & 1 \\ \cdot & 1 & -1 & \cdot \\ \cdot & 1 & 1 & \cdot \\ -1 & \cdot & \cdot & 1 \end{pmatrix} \tag{2.2.2}$$

and contains no free parameters (dots denote zeros). This R-matrix is strongly entangling. Note that the condition $R^8 = 1$ is satisfied. The defining relations for Artin's braid group allow also more general solutions obtained by multiplying R with an arbitrary phase factor. This would mean that $R^8 = 1$ constraint is not satisfied anymore. One can argue that over-all phase does not matter: on the other hand, the over all phase is visible in knot invariants defined by the trace of R.

The second and third solution come as families labelled four phases a, b, c and d:

$$R'(a,b,c,d) = \frac{1}{\sqrt{2}} \begin{pmatrix} a & \cdot & \cdot & \cdot \\ \cdot & & b & \cdot \\ \cdot & c & \cdot & \cdot \\ \cdot & \cdot & \cdot & d \end{pmatrix}$$

$$R''(a,b,c,d) = \frac{1}{\sqrt{2}} \begin{pmatrix} \cdot & \cdot & \cdot & a \\ \cdot & b & \cdot & \cdot \\ \cdot & \cdot & c & \cdot \\ d & \cdot & \cdot & \cdot \end{pmatrix} \tag{2.2.3}$$

These matrices are not as such entangling. The products $U_1 \otimes U_2 R V_1 \otimes V_2$, where U_i and V_i are 2×2 unitary matrices, are however entangling matrices and thus act as universal gates for $ad - bc \neq 0$ guaranteeing that the state $a|11\rangle + b|10\rangle + |01\rangle + |00\rangle$ is entangled.

It deserves to be noticed that the swap matrix

$$S = R'(1,1,1,1) = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & \cdot & \cdot & \cdot \\ \cdot & & 1 & \cdot \\ \cdot & 1 & 1 & \cdot \\ \cdot & \cdot & \cdot & 1 \end{pmatrix} \tag{2.2.4}$$

permuting the qubits does not define universal gate. This is understandable since in this representation of braid group reduces it to permutation group and situation becomes completely classical.

One can write all solutions R of braid Yang-Baxter equation in the form $R = R_a$, where R_a is the solution of so called algebraic Yang-Baxter equation. The interpretation is that the swap matrix S represents the completely classical part of the swap operation since it acts as a mere permutation whereas R_a represents genuine quantum effects related to the swap operation.

In the article of Kauffman [B36] its is demonstrated explicitly how to construct CNOT gate as a product MRN, where M and N are products of single particle gates. This article contains also a beautiful discussion about how the traces of the unitary matrices defined by the braids define knot invariants. For instance, the matrix R satisfies $R^8 = 1$ so that the invariants constructed using R as 2-gate cannot distinguish between knots containing n and $n + 8k$ sub-sequent swaps. Note however that the multiplication of R with a phase factor allows to get rid of the 8-periodicity.

Knots, links, braids, and quantum 2-gates

In [B36] basic facts about knots, links, and their relation to braids are discussed. Knot diagrams are introduced, the so called Reidermeister moves and homeomorphisms of plane as isotopies of knots and links are discussed. Also the notion of braid closure producing knots or links is introduced together with the theorem of Markov stating that any knot and link corresponds to some (not unique) braid. Markov moves as braid deformations leaving corresponding knots and links invariant are discussed and it the immediate implication is that traces of the braid matrices define knot invariants. In particular, the traces of the unitary matrices defined by R-matrix define invariants having same value for the knots and links resulting in the braid closure.

In [B36] the state preparation and quantum measurement allowing to deduce the absolute value of the trace of the unitary matrix associated with the braid defining the quantum computer is discussed as an example how quantum computations could occur in practice. The braid in question is product of the braid defining the invariant and trivial braid with same number n of strands. The incoming state is maximally entangled state formed $\sum_n |n\rangle \otimes |n\rangle$, where n runs over all possible bit sequences defined by the tensor product of n qubits. Quantum measurement performs a projection to this state and from the measurements it is possible to deduce the absolute value of the trace defining the knot invariant.

2.2.4 About Quantum Hall Effect And Theories Of Quantum Hall Effect

Using the dance metaphor for TQC, the system must be such that it is possible to distinguish between the different sexes of dancers. The proposal of [B23] is that the system exhibiting so called non-Abelian Quantum Hall effect [D11, D13] could make possible realization of the topological computation.

The most elegant models of quantum Hall effect are in terms of anyons regarded as singularities due to the symmetry breaking of gauge group G down to a finite sub-group H, which can be also non-Abelian. Concerning the description of the dynamics of topological degrees of freedom topological quantum field theories based on Chern-Simons action are the most promising approach.

Quantum Hall effect

Quantum Hall effect [D17, D11] occurs in 2-dimensional systems, typically a slab carrying a longitudinal voltage V causing longitudinal current j. A magnetic field orthogonal to the slab generates a transversal current component j_T by Lorentz force. j_T is proportional to the voltage V along the slab and the dimensionless coefficient is known as transversal conductivity. Classically the coefficients is proportional ne/B, where n is 2-dimensional electron density and should have a continuous spectrum. The finding that came as surprise was that the change of the coefficient as a function of parameters like magnetic field strength and temperature occurred as discrete steps of same size. In integer quantum Hall effect the coefficient is quantized to $2\nu\alpha$, $\alpha = e^2/4\pi$, such that ν is integer.

Later came the finding that also smaller steps corresponding to the filling fraction $\nu = 1/3$ of the basic step were present and could be understood if the charge of electron would have been replaced with $\nu = 1/3$ of its ordinary value. Later also QH effect with wide large range of filling fractions of form $\nu = k/m$ was observed.

The model explaining the QH effect is based on pseudo particles known as anyons [A21], [D11]. According to the general argument of [D17] anyons have fractional charge νe. Also the TGD based model for fractionization to be discussed later suggests that the anyon charge should be νe quite generally. The braid statistics of anyon is believed to be fractional so that anyons are neither bosons nor fermions. Non-fractional statistics is absolutely essential for the vacuum degeneracy used to represent logical qubits.

In the case of Abelian anyons the gauge potential corresponds to the vector potential of the divergence free velocity field or equivalently of incompressible anyon current. For non-Abelian anyons the field theory defined by Chern-Simons action is free field theory and in well-defined sense trivial although it defines knot invariants. For non-Abelian anyons situation would be different. They would carry non-Abelian gauge charges possibly related to a symmetry breaking to a discrete subgroup H of gauge group [A21] each of them defining an incompressible hydrodynamical flow. Non-Abelian QH effect has not yet been convincingly demonstrated experimentally. According to [B23] the anyons associated with the filling fraction $\nu = 5/2$ are a good candidate for non-Abelian anyons and in this case the charge of electron is reduced to $Q = 1/4$ rather than being $Q = \nu e$.

Non-Abelian anyons [D11, D12] are always created in pairs since they carry a conserved topological charge. In the model of [B23] this charge should have values in 4-element group Z_4 so that it is conserved only modulo 4 so that charges +2 and -2 are equivalent as are also charges 3 and -1. The state of n anyon pairs created from vacuum can be show to possess 2^{n-1}-dimensional vacuum degeneracy [D13]: later a TGD based argument for why this is the case is constructed. When two anyons fuse the 2^{n-1}-dimensional state space decomposes to 2^{n-2}-dimensional tensor factors corresponding to anyon Cooper pairs with topological charges 2 and 0. The topological "spin" is ideal for representing logical qubits. Since free topological charges are not possible the notion of physical qubit does not make sense (note the analogy with quarks). The measurement of topological qubit reduces to a measurement of whether anyon Cooper pair has vanishing topological charge or not.

Quantum Hall effect as a spontaneous symmetry breaking down to a discrete subgroup of the gauge group

The system exhibiting quantum Hall effect is effectively 2-dimensional. Fractional statistics suggests that topological defects, anyons, allowing a description in terms of the representations of the homotopy group of $((R^2)^n - D)/S_n$. The gauge theory description would be in terms of spontaneous symmetry breaking of the gauge group G to a finite subgroup H by a Higgs mechanism [A21] , [D11]. This would make all gauge degrees of freedom massive and leave only topological degrees of freedom. What is unexpected that also non-Abelian topological degrees of freedom are in principle possible. Quantum Hall effect is Abelian or non-Abelian depending on whether the group H has this property.

In the symmetry breaking $G \rightarrow H$ the non-Abelian gauge fluxes defined as non-integrable phase factors $Pexp(i \oint A_\mu dx^\mu)$ around large circles (surrounding singularities (so that field approaches a pure gauge configuration) are elements of the first homotopy group of G/H, which is H in the case that H is discrete group and G is simple. An idealized manner to model the situation [D11] is to assume that the connection is pure gauge and defined by an H-valued function which is many-valued such that the values for different branches are related by a gauge transformation in H. In the general case a gauge transformation of a non-trivial gauge field by a multi-valued element of the gauge group would give rise to a similar situation.

One can characterize a given topological singularity magnetically by an element in conjugacy class C of H representing the transformation of H induced by a 2π rotation around singularity. The elements of C define states in given magnetic representation. Electrically the particles are characterized by an irreducible representations of the subgroup of $H_C \subset H$ which commutes with an arbitrarily chosen element of the conjugacy class C.

The action of $h(B)$ resulting on particle A when it makes a closed turn around B reduces in magnetic degrees of freedom to translation in conjugacy class combined with the action of element of H_C in electric degrees of freedom. Closed paths correspond to elements of the braid group $B_n(X^2)$ identifiable as the mapping class group of the punctured 2-surface X^2 and this means that symmetry breaking $G \rightarrow H$ defines a representation of the braid group. The construction of these representations is discussed in [D11] and leads naturally via the group algebra of H to the so called quantum double $D(H)$ of H, which is a quasi-triangular Hopf algebra allowing non-trivial representations of braid group.

Anyons could be singularities of gauge fields, perhaps even non-Abelian gauge fields, and the latter ones could be modelled by these representations. In particular, braid operations could be represented using anyons.

Witten-Chern-Simons action and topological quantum field theories

The Wess-Zumino-Witten action used to model 2-dimensional critical systems consists of a 2-dimensional conformally invariant term for the chiral field having values in group G combined with 2+1-dimensional term defined as the integral of Chern-Simons 3-form over a 3-space containing 2-D space as its boundary. This term is purely topological and identifiable as winding number for the map from 3-dimensional space to G. The coefficient of this term is integer k in suitable normalization. k gives the value of central extension of the Kac-Moody algebra defined by the theory.

One can couple the chiral field $g(x)$ to gauge potential defined for some subgroup of G_1 of G. If the G_1 coincides with G, the chiral field can be gauged away by a suitable gauge transformation and the theory becomes purely topological Witten-Chern-Simons theory. Pure gauge field configuration represented either as flat gauge fields with non-trivial holonomy over homotopically non-trivial paths or as multi-valued gauge group elements however remain and the remaining degrees of freedom correspond to the topological degrees of freedom.

Witten-Chern-Simons theories are labelled by a positive integer k giving the value of central extension of the Kac-Moody algebra defined by the theory. The connection with Wess-Zumino-Witten theory come from the fact that the highest weight states associated with the representations of the Kac-Moody algebra of WZW theory are in one-one correspondence with the representations R_i possible for Wilson loops in the topological quantum field theory.

In the Abelian case case 2+1-dimensional Chern-Simons action density is essentially the inner product $A \wedge dA$ of the vector potential and magnetic field known as helicity density and the theory in question is a free field theory. In the non-Abelian case the action is defined by the 3-form

$$\frac{k}{4\pi}Tr\left(A \wedge (dA + \frac{2}{3}A \wedge A)\right)$$

and contains also interaction term so that the field theory defined by the exponential of the interaction term is non-trivial.

In topological quantum field theory the usual n-point correlation functions defined by the functional integral are replaced by the functional averages for $Diff^3$ invariant quantities defined in terms of non-integrable phase factors defined by ordered exponentials over closed loops. One can consider arbitrary number of loops which can be knotted, linked, and braided. These quantities define both knot and 3-manifold invariants (the functional integral for zero link in particular). The perturbative calculation of the quantum averages leads directly to the Gaussian linking numbers and infinite number of perturbative link and not invariants.

The experience gained from topological quantum field theories defined by Chern-Simons action has led to a very elegant and surprisingly simple category theoretical approach to the topological quantum field theory [A6, A24] allowing to assign invariants to knots, links, braids, and tangles and also to 3-manifolds for which braids as morphisms are replaced with cobordisms. The so called modular Hopf algebras, in particular quantum groups $Sl(2)_q$ with q a root of unity, are in key role in this approach. Also the connection between links and 3-manifolds can be understood since closed, oriented, 3-manifolds can be constructed from each other by surgery based on links.

Witten's article [A11] "Quantum Field Theory and the Jones Polynomial" is full of ingenious constructions, and for a physicist it is the easiest and certainly highly enjoyable manner to learn about knots and 3-manifolds. For these reasons a little bit more detailed sum up is perhaps in order.

1. Witten discusses first the quantization of Chern-Simons action at the weak coupling limit $k \to \infty$. First it is shown how the functional integration around flat connections defines a topological invariant for 3-manifolds in the case of a trivial Wilson loop. Next a canonical quantization is performed in the case $X^3 = \Sigma^2 \times R^1$: in the Coulomb gauge $A_3 = 0$ the action reduces to a sum of $n = dim(G)$ Abelian Chern-Simons actions with a non-linear constraint expressing the vanishing of the gauge field. The configuration space consists thus of flat non-Abelian connections, which are characterized by their holonomy groups and allows Kähler manifold structure.

2. Perhaps the most elegant quantal element of the approach is the decomposition of the 3-manifold to two pieces glued together along 2-manifold implying the decomposition of the functional integral to a product of functional integrals over the pieces. This together with the basic properties of Hilbert of complex numbers (to which the partition functions defined by the functional integrals over the two pieces belong) allows almost a miracle like deduction of the basic results about the behavior of 3-manifold and link invariants under a connected sum, and leads to the crucial skein relations allowing to calculate the invariants by decomposing the link step by step to a union of unknotted, unlinked Wilson loops, which can be calculated exactly for $SU(N)$. The decomposition by skein relations gives rise to a partition function like representation of invariants and allows to understand the connection between knot theory and statistical [A27]. A direct relationship with conformal field theories and Wess-Zumino-Witten model emerges via Wilson loops associated with the highest weight representations for Kac Moody algebras.

3. A similar decomposition procedure applies also to the calculation of 3-manifold invariants using link surgery to transform 3-manifolds to each other, with 3-manifold invariants being defined as Wilson loops associated with the homology generators of these (solid) tori using representations R_i appearing as highest weight representations of the loop algebra of torus. Surgery operations are represented as mapping class group operations acting in the Hilbert space defined by the invariants for representations R_i for the original 3-manifold. The outcome is explicit formulas for the invariants of trivial knots and 3-manifold invariant of S^3 for $G = SU(N)$, in terms of which more complex invariants are expressible.

4. For $SU(N)$ the invariants are expressible as functions of the phase $q = exp(i2\pi/(k+N))$ associated with quantum groups. Note that for $SU(2)$ and $k = 3$, the invariants are expressible in terms of Golden Ratio. The central charge $k = 3$ is in a special position since it gives rise to $k+1 = 4$-vertex representing naturally 2-gate physically. Witten-Chern-Simons theories define universal unitary modular functors characterizing quantum computations [B28].

Chern-Simons action for anyons

In the case of quantum Hall effect the Chern-Simons action has been deduced from a model of electrons as a 2-dimensional incompressible fluid [D14]. Incompressibility requires that the electron current has a vanishing divergence, which makes it analogous to a magnetic field. The expressibility of the current as a curl of a vector potential b, and a detailed study of the interaction Lagrangian leads to the identification of an Abelian Chern-Simons for b as a low energy effective action. This action is Abelian, whereas the anyonic realization of quantum computation would suggest a non-Abelian Chern-Simons action.

Non-Abelian Chern-Simons action could result in the symmetry breaking of a non-Abelian gauge group G, most naturally electro-weak gauge group, to a non-Abelian discrete subgroup H [A21] so that states would be labelled by representations of H and anyons would be characterized magnetically H-valued non-Abelian magnetic fluxes each of them defining its own incompressible hydro-dynamical flow. As will be found, TGD predicts a non-Abelian Chern-Simons term associated with electroweak long range classical fields.

2.2.5 Topological Quantum Computation Using Braids And Anyons

By the general mathematical results braids are able to code all quantum logic operations [B6]. In particular, braids allow to realize any quantum circuit consisting of single particle gates acting on qubits and two particle gates acting on pairs of qubits. The coding of braid requires a classical computation which can be done in polynomial time. The coding requires that each dancer is able to remember its dancing history by coding it into its own state.

The general ideas are following.

1. The ground states of anyonic system characterize the logical qubits, One assumes non-Abelian anyons with Z_4 -valued topological charge so that a system of n anyon pairs created from vacuum allows 2^{n-1}-fold anyon degeneracy [D13]. The system is decomposed into blocks containing one anyonic Cooper pair with $Q_T \in \{2,0\}$ and two anyons with such topological charges that the net topological charge vanishes. One can say that the states $(0,1-1)$ and $(0,-1,+1))$ represent logical qubit 0 whereas the states $(2,-1,-1)$ and $(2,+1,+1)$ represent logical qubit 1. This would suggest 2^2-fold degeneracy but actually the degeneracy is 2-fold.

   Free physical qubits are not possible and at least four particles are indeed necessarily in order to represent logical qubit. The reason is that the conservation of Z^4 charge would not allow mixing of qubits 1 and 0, in particular the Hadamard 1-gate generating square root of qubit would break the conservation of topological charge. The square root of qubit can be generated only if 2 units of topological charge is transferred between anyon and anyon Cooper pair. Thus qubits can be represented as entangled states of anyon Cooper pair and anyon and the fourth anyon is needed to achieve vanishing total topological charge in the batch.

2. In the initial state of the system the anyonic Cooper pairs have $Q_T = 0$ and the two anyons have opposite topological charges inside each block. The initial state codes no information unlike in ordinary computation but the information is represented by the braid. Of course, also more general configurations are possible. Anyons are assumed to evolve like free particles except during swap operations and their time evolution is described by single particle Hamiltonians.

   Free particle approximation fails when the anyons are too near to each other as during braid operations. The space of logical qubits is realized as k-code defined by the 2^{n-1} ground states, which are stable against local single particle perturbations for $k = 3$ Witten-Chern-Simons action. In the more general case the stability against n-particle perturbations with

$n < [k/2]$ is achieved but the gates would become $[k/2]$-particle gates (for $k = 5$ this would give 6-particle vertices).

3. Anyonic system provides a unitary modular functor as the S-matrix associated with the anyon system whose time evolution is fixed by the pre-existing braid structure. What this means that the S-matrices associated with the braids can be multiplied and thus a unitary representation for the group formed by braids results. The vacuum degeneracy of anyon system makes this representation non-trivial. By the NP complexity of braids it is possible to code any quantum logic operation by a particular braid [B39]. There exists a powerful approximation theorem allowing to achieve this coding classically in polynomial time [B6]. From the properties of the R-matrices inducing gate operations it is indeed clear that two gates can be realized. The Hadamard 1-gate could be realized as 2-gate in the system formed by anyon Cooper pair and anyon.

4. In [B23] the time evolution is regarded as a discrete sequence of modifications of single anyon Hamiltonians induced by swaps [B40]. If the modifications define a closed loop in the space of Hamiltonians the resulting unitary operators define a representation of braid group in a dense discrete sub-group of $U(2^n)$. The swap operation is 2-local operation acting like a 2-gate and induces quantum logical operation modifying also single particle Hamiltonians. What is important that this modification maps the space of the ground states to a new one and only if the modifications correspond to a closed loop the final state is in the same code space as the initial state. What time evolution does is to affect the topological charges of anyon Cooper pairs representing qubits inside the 4-anyon batches defined by the braids.

   In quantum field theory the analog but not equivalent of this description would be following. Quite generally, a given particle in the final state has suffered a unitary transformation, which is an ordered product consisting of two kinds of unitary operators. Unitary single particle operators $U_n = Pexp(i\int_{t_n}^{t_{n+1}} H_0 dt)$ are analogs of operators describing single qubit gate and play the role of anyon propagators during no-swap periods. Two-particle unitary operators $U_{swap} = Pexp(i\int H_{swap} dt)$ are analogous to four-particle interactions and describe the effect of braid operations inducing entanglement of states having opposite values of topological charge but conserving the net topological charge of the anyon pair. This entanglement is completely analogous to spin entanglement. In particular, the braid operation mixes different states of the anyon. The unitary time development operator generating entangled state of anyons and defined by the braid structure represents the operation performed by the quantum circuit and the quantum measurement in the final state selects a particular final state.

5. Formally the computation halts with a measurement of the topological charge of the left-most anyon Cooper pair when the outcome is just single bit. If decay occurs with sufficiently high probability it is concluded that the value of the computed bit is 0, otherwise 1.

2.3 General Implications Of TGD For Quantum Computation

TGD based view about time and space-time could have rather dramatic implications for quantum computation in general and these implications deserve to be discussed briefly.

2.3.1 Time Need Not Be A Problem For Quantum Computations In TGD Universe

Communication with and control of the geometric past is the basic mechanism of intentional action, sensory perception, and long term memory in TGD inspired theory of consciousness. The possibility to send negative energy signals to the geometric past allows also instantaneous computations with respect to subjective time defined by a sequence of quantum jumps. The outcome of computation back to the past where it defines initial values of the next round of iteration. Time would cease to be a limiting factor to computation.

2.3.2 New View About Information

The notion of information is very problematic even in the classical physics and in quantum realm this concept becomes even more enigmatic. TGD inspired theory consciousness has inspired number theoretic ideas about quantum information which are still developing. The standard definition of entanglement entropy relies on the Shannon's formula: $S = -\sum_k p_k log(p_k)$. This entropy is always non-negative and tells that the best one can achieve is entanglement with zero entropy.

The generalization of the notion of entanglement entropy to the p-adic context however led to realization that entanglement for which entanglement probabilities are rational or in an extension of rational numbers defining a finite extension of p-adics allows a hierarchy of entanglement entropies S_p labelled by primes. These entropies are defined as $S_p = -\sum_k p_k log(|p_k|_p)$, where $|p_k|_p$ denotes the p-adic norm of probability. S_p can be negative and in this case defines a genuine information measure. For given entanglement probabilities S_p has a minimum for some value p_0 of prime p, and S_{p_0} could be taken as a measure for the information carried by the entanglement in question whereas entanglement in real and p-adic continua would be entropic. The entanglement with negative entanglement entropy is identified as bound state entanglement.

Since quantum computers by definition apply states for which entanglement coefficients belong to a finite algebraic extension of rational numbers, the resulting states, if ideal, should be bound states. Also finite-dimensional extensions of p-adic numbers by transcendentals are possible. For instance, the extension by the $p-1$ first powers of e (e^p is ordinary p-adic number in R_p). As an extension of rationals this extension would be discrete but infinite-dimensional. Macro-temporal quantum coherence can be identified as being due to bound state formation in appropriate degrees of freedom and implying that state preparation and state function reduction effectively ceases to occur in these degrees of freedom.

Macro-temporal quantum coherence effectively binds a sequence of quantum jumps to single quantum jump so that the effective duration of unitary evolution is stretched from about 10^4 Planck times to arbitrary long time span. Also quantum computations can be regarded as this kind of extended moments of consciousness.

2.3.3 Number Theoretic Vision About Quantum Jump As A Building Block Of Conscious Experience

The generalization of number concept resulting when reals and various p-adic number fields are fused to a book like structure obtaining by gluing them along rational numbers common to all these number fields leads to an extremely general view about what happens in quantum jump identified as basic building block of conscious experience. First of all, the unitary process U generates a formal superposition of states belonging to different number fields including their extensions. Negentropy Maximization Principle [K58] constrains the dynamics of state preparation and state function reduction following U so that the final state contains only rational or extended rational entanglement with positive information content. At the level of conscious experience this process can be interpreted as a cognitive process or analysis leading to a state containing only bound state entanglement serving as a correlate for the experience of understanding. Thus quantum information science and quantum theory of consciousness seem to meet each other.

In the standard approach to quantum computing entanglement is not bound state entanglement. If bound state entanglement is really the entanglement which is possible for quantum computer, the entanglement of qubits might not serve as a universal entanglement currency. That is, the reduction of the general two-particle entanglement to entanglement between N qubits might not be possible in TGD framework.

The conclusion that only bound state entanglement is possible in quantum computation in human time scales is however based on the somewhat questionable heuristic assumption that subjective time has the same universal rate, that is the average increment Δt of the geometric time in single quantum jump does not depend on the space-time sheet, and is of order CP_2 time about 10^4 Planck times. The conclusion could be circumvented if one assumes that Δt depends on the space-time sheet involved: for instance, instead of CP_2 time Δt could be of order p-adic time scale T_p for a space-time sheet labelled by p-adic prime p and increase like $\sqrt{p}$. In this case the unitary operator defining quantum computation would be simply that defining the unitary process U.

2.3.4 Dissipative Quantum Parallelism?

The new view about quantum jump implies that state function reduction and preparation process decomposes into a hierarchy of these processes occurring in various scales: dissipation would occur in quantum parallel manner with each p-adic scale defining one level in the hierarchy. At space-time level this would correspond to almost independent quantum dynamics at parallel space-time sheets labelled by p-adic primes. In particular, dissipative processes can occur in short scales while the dynamics in longer scales is non-dissipative. This would explain why the description of hadrons as dissipative systems consisting of quarks and gluons in short scales is consistent with the description of hadrons as genuine quantum systems in long scales. Dissipative quantum parallelism would also mean that thermodynamics at shorter length scales would stabilize the dynamics at longer length scales and in this manner favor scaled up quantum coherence.

NMR systems [B5] might represent an example about dissipative quantum parallelism. Room temperature NMR (nuclear magnetic resonance) systems use highly redundant replicas of qubits which have very long coherence times. Quantum gates using radio frequency pulses to modify the spin evolution have been implemented, and even effective Hamiltonians have been synthesized. Quantum computations and dynamics of other quantum systems have been simulated and quantum error protocols have been realized. These successes are unexpected since the energy scale of cyclotron states is much below the thermal energy. This has raised fundamental questions about the power of quantum information processing in highly mixed states, and it might be that dissipative quantum parallelism is needed to explain the successes.

Magnetized systems could realize quite concretely the renormalization group philosophy in the sense that the magnetic fields due to the magnetization at the atomic space-time sheets could define a return flux along larger space-time sheets as magnetic flux quanta (by topological flux quantization) defining effective block spins serving as thermally stabilized qubits for a long length scale quantum parallel dynamics. For an external magnetic field $B \sim 10$ Tesla the magnetic length is $L \sim 10$ nm and corresponds to the p-adic length scale $L(k = 151)$. The induced magnetization is $M \sim n\mu^2 B/T$, where n is the density of nuclei and $\mu = ge/2m_p$ is the magnetic moment of nucleus. For solid matter density the magnetization is by a factor ~ 10 weaker than the Earth's magnetic field and corresponds to a magnetic length $L \sim 15$ μm: the p-adic length scale is around $L(171)$. For 10^{22} spins per block spin used for NMR simulations the size of block spin should be $\sim$ 1mm solid matter density so that single block spin would contain roughly 10^6 magnetization flux quanta containing 10^{16} spins each. The magnetization flux quanta serving as logical qubits could allow to circumvent the standard physics upper bound for scaling up of about 10 logical qubits [B5].

2.3.5 Negative Energies And Quantum Computation

In TGD universe space-times are 4-surfaces so that negative energies are possible due to the fact that the sign of energy depends on time orientation (energy momentum tensor is replaced by a collection of conserved momentum currents). This has several implications. Negative energy photons having phase conjugate photons as physical correlates of photons play a key role in TGD inspired theory of consciousness and living matter and there are also indications that magnetic flux tubes structures with negative energies are important.

Negative energies makes possible communications to the geometric past, and time mirror mechanism (see **Fig. ??** in the appendix of this book) involving generation of negative energy photons is the key mechanism of intentional action and plays central role in the model for the functioning of bio-systems. In principle this could allow to circumvent the problems due to the time required by computation by initiating computation in the geometric past and iterating this process. The most elegant and predictive cosmology is that for which the net conserved quantities of the universe vanish due the natural boundary condition that nothing flows into the future light cone through its boundaries representing the moment of big bang.

Also topological quantum field theories describe systems for which conserved quantities associated with the isometries of space-time, such as energy and momentum, vanish. Hence the natural question is whether negative energies making possible zero energy states might also make possible also zero energy quantum computations.

Crossing symmetry and Eastern and Western views about what happens in scattering

The hypothesis that all physical states have vanishing net quantum numbers (Eastern view) forces to interpret the scattering events of particle physics as quantum jumps between different vacua. This interpretation is in a satisfactory consistency with the assumption about existence of objective reality characterized by a positive energy (Western view) if crossing symmetry holds so that WCW spinor fields can be regarded as S-matrix elements between initial state defined by positive energy particles and negative energy state defined by negative energy particles. As a matter fact, the proposal for the S-matrix of TGD at elementary particle level relies on this idea: the amplitudes for the transition from vacuum to states having vanishing net quantum numbers with positive and negative energy states interpreted as incoming and outgoing states are assumed to be interpretable as S-matrix elements.

More generally, one could require that scattering between any pair of states with zero net energies and representing S-matrix allows interpretation as a scattering between positive energy states. This requirement is satisfied if their exists an entire self-reflective hierarchy of S-matrices in the sense that the S-matrix between states representing S-matrices S_1 and S_2 would be the tensor product $S_1 \otimes S_2$. At the observational level the experience the usual sequence of observations $|m_1\rangle \rightarrow |m_2\rangle..... \rightarrow |m_n\rangle...$ based on belief about objective reality with non-vanishing conserved net quantum numbers would correspond to a sequence $(|m_1 \rightarrow m_2\rangle \rightarrow |m_2 \rightarrow m_3\rangle...$ between "self-reflective" zero energy states. These sequences are expected to be of special importance since the contribution of the unit matrix to S-matrix $S = 1 + iT$ gives dominating contribution unless interactions are strong. This sequence would result in the approximation that $S_2 = 1 + iT_2$ in $S = S_1 \otimes S_2$ is diagonal. The fact that the scattering for macroscopic systems tends to be in forward direction would help to create the materialistic illusion about unique objective reality.

It should be possible to test whether the Eastern or Western view is correct by looking what happens strong interacting systems where the western view should fail. The Eastern view is consistent with the basic vision about quantum jumps between quantum histories having as a counterpart the change of the geometric past at space-time level.

Negative energy anti-fermions and matter-antimatter asymmetry

The assumption that space-time is 4-surface means that the sign of energy depends on time orientation so that negative energies are possible. Phase conjugate photons [D16] are excellent candidates for negative energy photons propagating into geometric past.

Also the phase conjugate fermions make in principle sense and one can indeed perform Dirac quantization in four ways such that a) both fermions and anti-fermions have positive/negative energies, b) fermions (anti-fermions) have positive energies and anti-fermions (fermions) have negative energies. The corresponding ground state correspond to Dirac seas obtained by applying the product of a) all fermionic and anti-fermionic annihilation (creation) operators to vacuum, b) all fermionic creation (annihilation) operators and anti-fermionic annihilation (creation) operators to vacuum. The ground states of a) have infinite vacuum energy which is either negative or positive whereas the ground states of b) have vanishing vacuum energy. The case b) with positive fermionic and negative anti-fermionic energies could correspond to long length scales in which are matter-antisymmetric due to the effective absence of anti-fermions ("effective" meaning that no-one has tried to detect the negative energy anti-fermions). The case a) with positive energies could naturally correspond to the phase studied in elementary particle physics.

If gravitational and inertial masses have same magnitude and same sign, consistency with empirical facts requires that positive and negative energy matter must have been separated in cosmological length scales. Gravitational repulsion might be the mechanism causing this. Applying naïvely Newton's equations to a system of two bodies with energies $E_1 > 0$ and $-E_2 < 0$ and assuming only gravitational force, one finds that the sign of force for the motion in relative coordinates is determined by the sign of the reduced mass $-E_1E_2/(E_1 - E_2)$, which is negative for $E_1 > |E_2|$: positive masses would act repulsively on smaller negative masses. For $E_1 = -E_2$ the motion in the relative coordinate becomes free motion and both systems experience same acceleration which for E_1 corresponds to a repulsive force. The reader has probably already asked whether the observed acceleration of the cosmological expansion interpreted in terms of cosmological constant due to vacuum energy could actually correspond to a repulsive force between positive and negative energy matter.

It is possible to create pairs of positive energy fermions and negative energy fermions from vacuum. For instance, annihilation of photons and phase conjugate photons could create electron and negative energy positron pairs with a vanishing net energy. Magnetic flux tubes having positive and negative energies carrying fermions and negative energy positrons pairs of photons and their phase conjugates via fermion anti-fermion annihilation. The obvious idea is to perform zero energy topological quantum computations by using anyons of positive energy and anti-anyons of negative energy plus their Cooper pairs. This idea will be discussed later in more detail.

2.4 TGD Based New Physics Related To Topological Quantum Computation

For a long the belief was that absolute minimum property defines the basic dynamical principle of space-time physics. This might make sense in space-time regions of Euclidian signature, where Kähler action is non-negative but not in Minkowskian regions, where the contribution to the exponent defining vacuum functional is imaginary. The reduction of the theory to the level of Kähler-Dirac action [K111] made it however clear that the preferred extremals defining the analogs of Bohr orbits must be critical in the sense of having an infinite number of deformations for which the second variation of Kähler action vanishes. The criticality of Kähler action would thus the basic dynamical principle of space-time dynamics. Purely number theoretic conditions in turn suggest the conclusion that space-time surfaces must be hyper-quaternionic in the sense that the Kähler-Dirac gamma matrices span hyper-quaternionic (asociative) or co-hyper-quaternionic (co-associative) plane at each point of the spacce-time surface. "Co-" means that the orthogonal complement of this plane is hyper-quaternionic (associative). Whether criticality and associativity (co-associativity) are consistent is not clear.

For a long time it remained an open question whether the known solutions of field equations are building blocks of preferred extremals of Kähler action or represent only the simplest extremals one can imagine and perhaps devoid of any real significance. Quantum-classical correspondence meant a great progress in the understanding the solution spectrum of field equations. Among other things, this principle requires that the dissipative quantum dynamics leading to non-dissipating asymptotic self-organization patterns should have the vanishing of the Lorentz 4-force as space-time correlate. The absence of dissipation in the sense of vanishing of Lorentz 4-force is a natural correlate for the absence of dissipation in quantum computations.

The vanishing of Lorentz 4-force generalizes the so called Beltrami conditions [B9, B14] stating the vanishing of Lorentz force for purely magnetic field configurations and these conditions reduce in many cases to topological conditions. The study of classical field equations predicts three phases corresponding to non-vacuum solutions of field equations possessing vanishing Lorentz force. The dimension D of CP_2 projection of the space-time sheet serves as classifier of the phases.

1. $D = 2$ phase is analogous to ferro-magnetic phase possible in low temperatures and relatively simple, $D = 4$ phase is in turn analogous to a chaotic de-magnetized high temperature phase.

2. $D = 3$ phase represents spin glass phase, kind of boundary region between order and chaos possible in a finite temperature range and is an ideal candidate for the field body serving as a template for living systems. $D = 3$ phase allows infinite number of conserved topological charges having interpretation as invariants describing the linking of the magnetic field lines. This phase is also the phase in which topological quantum computations are possible.

2.4.1 Topologically Quantized Generalized Beltrami Fields And Braiding

From the construction of the solutions of field equations in terms topologically quantized fields it is obvious that TGD Universe is tailor made for TQC.

$D = 3$ phase allows infinite number of topological charges characterizing the linking of magnetic field lines

When space-time sheet possesses a $D = 3$-dimensional CP_2 projection, one can assign to it a non-vanishing and conserved topological charge characterizing the linking of the magnetic field lines defined by Chern-Simons action density $A \wedge dA/4\pi$ for induced Kähler form. This charge can be seen as classical topological invariant of the linked structure formed by magnetic field lines. For $D = 2$ the topological charge densities vanish identically, for $D = 3$ they are in general non-vanishing and conserved, whereas for $D = 4$ they are not conserved. The transition to $D = 4$ phase can thus be used to erase quantum computer programs realized as braids. The 3-dimensional CP_2 projection provides an economical manner to represent the braided world line pattern of dancers and would be the space where the 3-dimensional quantum field theory would be defined.

The topological charge can also vanish for $D = 3$ space-time sheets. In Darboux coordinates for which Kähler gauge potential reads as $A = P_k dQ^k$, the surfaces of this kind result if one has $Q^2 = f(Q^1)$ implying $A = fdQ^1$, $f = P_1 + P_2\partial_{Q_1}Q^2$, which implies the condition $A \wedge dA = 0$. For these space-time sheets one can introduce Q^1 as a global coordinate along field lines of A and define the phase factor $exp(i\int A_\mu dx^\mu)$ as a wave function defined for the entire space-time sheet. This function could be interpreted as a phase of an order order parameter of super-conductor like state and there is a high temptation to assume that quantum coherence in this sense is lost for more general $D = 3$ solutions. Note however that in boundaries can still remain super-conducting and it seems that this occurs in the case of anyons.

Chern-Simons action is known as helicity in electrodynamics [B31]. Helicity indeed describes the linking of magnetic flux lines as is easy to see by interpreting magnetic field as incompressible fluid flow having A as vector potential: $B = \nabla \times A$. One can write A using the inverse of $\nabla\times$ as $A = (1/\nabla\times)B$. The inverse is non-local operator expressible as

$$\frac{1}{\nabla\times}B(r) = \int dV' \frac{(r-r')}{|r-r'|^3} \times B(r') \ ,$$

as a little calculation shows. This allows to write $\int A \cdot B$ as

$$\int dV A \cdot B = \int dV dV' B(r) \cdot \left(\frac{(r-r')}{|r-r'|^3} \times B(r') \right) \ ,$$

which is completely analogous to the Gauss formula for linking number when linked curves are replaced by a distribution of linked curves and an average is taken.

For $D = 3$ field equations imply that Kähler current is proportional to the helicity current by a factor which depends on CP_2 coordinates, which implies that the current is automatically divergence free and defines a conserved charge for $D = 3$-dimensional CP_2 projection for which the instanton density vanishes identically. Kähler charge is not equal to the helicity defined by the inner product of magnetic field and vector potential but to a more general topological charge.

The number of conserved topological charges is infinite since the product of any function of CP_2 coordinates with the helicity current has vanishing divergence and defines a topological charge. A very natural function basis is provided by the scalar spherical harmonics of $SU(3)$ defining Hamiltonians of CP_2 canonical transformations and possessing well defined color quantum numbers. These functions define and infinite number of conserved charges which are also classical knot invariants in the sense that they are not affected at all when the 3-surface interpreted as a map from CP_2 projection to M^4_+ is deformed in M^4_+ degrees of freedom. Also canonical transformations induced by Hamiltonians in irreducible representations of color group affect these invariants via Poisson bracket action when the $U(1)$ gauge transformation induced by the canonical transformation corresponds to a single valued scalar function. These link invariants are additive in union whereas the quantum invariants defined by topological quantum field theories are multiplicative.

Also non-Abelian topological charges are well-defined. One can generalize the topological current associated with the Kähler form to a corresponding current associated with the induced electro-weak gauge fields whereas for classical color gauge fields the Chern-Simons form vanishes identically. Also in this case one can multiply the current by CP_2 color harmonics to obtain an infinite number of invariants in $D = 3$ case. The only difference is that $A \wedge dA$ is replaced by $Tr(A \wedge (dA + 2A \wedge A/3))$.

There is a strong temptation to assume that these conserved charges characterize colored quantum states of the conformally invariant quantum theory as a functional of the light-like 3-surface defining boundary of space-time sheet or elementary particle horizon surrounding wormhole contacts. They would be TGD analogs of the states of the topological quantum field theory defined by Chern-Simons action as highest weight states associated with corresponding Wess-Zumino-Witten theory. These charges could be interpreted as topological counterparts of the isometry charges of WCW of 3-surfaces defined by the algebra of canonical transformations of CP_2.

The interpretation of these charges as contributions of light-like boundaries to WCW Hamiltonians would be natural. The dynamics of the induced second quantized spinor fields relates to that of Kähler action by a super-symmetry, so that it should define super-symmetric counterparts of these knot invariants. The anti-commutators of these super charges would contribute to WCW metric a part which would define a Kähler magnetic knot invariant. These Hamiltonians and their super-charge counterparts would be responsible for the topological sector of quantum TGD.

The color partial wave degeneracy of topological charges inspires the idea that also anyons could move in color partial waves identifiable in terms of "rigid body rotation" of the magnetic flux tube of anyon in CP_2 degrees of freedom. Their presence could explain non-Abelianity of Chern-Simons action and bring in new kind bits increasing the computational capacity of the topological quantum computer. The idea about the importance of macroscopic color is not new in TGD context. The fact that non-vanishing Kähler field is always accompanied by a classical color field (proportional to it) has motivated the proposal that colored excitations in macroscopic length scales are important in living matter and that colors as visual qualia correspond to increments of color quantum numbers in quantum phase transitions giving rise to visual sensations.

Knot theory, 3-manifold topology, and $D = 3$ solutions of field equations

Topological quantum field theory (TQFT) [A24] demonstrates a deep connection between links and 3-topology, and one might hope that this connection could be re-interpreted in terms of embeddings of 3-manifolds to $H = M^4_+ \times CP_2$ as surfaces having 3-dimensional CP_2 projection, call it X^3 in the sequel. $D = 3$ suggests itself because in this case Chern-Simons action density for the induced Kähler field is generically non-vanishing and defines an infinite number of classical charges identifiable as Kähler magnetic canonical covariants invariant under $Diff(M^4_+)$. The field topology of Kähler magnetic field should be in a key role in the understanding of these invariants.

1. Could 3-D CP_2 projection of 3-surface provide a representation of 3-topology?

Witten-Chern-Simons theory for a given 3-manifold defines invariants which characterize both the topology of 3-manifold and the link. Why this is the case can be understood from the construction of 3-manifolds by drilling a tubular neighborhood of a link in S^3 and by gluing the tori back to get a new 3-manifolds. The links with some moves defining link equivalences are known to be in one-one correspondence with closed 3-manifolds and the axiomatic formulation of TQFT [A24] as a modular functor clarifies this correspondence. The question is whether the CP_2 projection of the 3-surface could under some assumptions be represented by a link so that one could understand the connection between the links and topology of 3-manifolds.

In order to get some idea about what might happen consider the CP_2 projection X^3 of 3-surface. Assume that X^3 is obtained from S^3 represented as a 3-surface in CP_2 by removing from S^3 a tubular link consisting of linked and knotted solid tori $D^2 \times S^1$. Since the 3-surface is closed, it must have folds at the boundaries being thus representable as a two-valued map $S^3 \rightarrow M^4_+$ near the folds. Assume that this is the case everywhere. The two halves of the 3-surface corresponding to the two branches of the map would be glued together along the boundary of the tubular link by identification maps which are in the general case characterized by the mapping class group of 2-torus. The gluing maps are defined inside the overlapping coordinate batches containing the boundary $S^1 \times S^1$ and are maps between the pairs (Ψ_i, Φ_i), $i = 1, 2$ of the angular coordinates parameterizing the tori.

Define longitude as a representative for the $a + nb$ of the homology group of the 2-torus. The integer n defines so called framing and means that the longitude twists n times around torus. As a matter fact, TQFT requires bi-framing: at the level of Chern-Simons perturbation theory bi-framing is necessary in order to define self linking numbers. Define meridian as the generator of the homology group of the complement of solid torus in S^3. It is enough to glue the carved torus back in such a way that meridian is mapped to longitude and longitude to minus meridian. This map corresponds to the $SL(2,C)$ element

$$\begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} .$$

Also other identification maps defined by $SL(2,Z)$ matrices are possible but one can do using only this. Note that the two component $SL(2,Z)$ spinors defined as superpositions of the generators (a,b) of the homology group of torus are candidates for the topological correlates of spinors. In the gluing process the tori become knotted and linked when seen in the coordinates of the complement of the solid tori.

This construction would represent the link surgery of 3-manifolds in terms of CP_2 projections of 3-surfaces of H. Unfortunately this representation does not seem to be the only one. One can construct closed three-manifolds also by the so called Heegaard splitting. Remove from S^3 D_g, a solid sphere with g handles having boundary S_g, and glue the resulting surface with its oppositely oriented copy along boundaries. The gluing maps are classified by the mapping class group of S_g. Any closed orientable 3-manifold can be obtained by this kind of procedure for some value of g. Also this construction could be interpreted in terms of a fold at the boundary of the CP_2 projection for a 2-valued graph $S^3 \rightarrow M^4_+$. Whether link surgery representation and Heegaard splitting could be transformed to each other by say pinching D_g to separate tori is not clear to me.

When the graph $CP_2 \rightarrow M^4_+$ is at most 2-valued, the intricacies due to the embedding of the 3-manifold are at minimum, and the link associated with the projection should give information about 3-topology and perhaps even characterize it. Also the classical topological charges associated with Kähler Chern-Simons action could give this kind of information.

2. Knotting and linking for 3-surfaces

The intricacies related to embedding become important in small co-dimensions and it is of considerable interest to find what can happen in the case of 3-surfaces. For 1-dimensional links and knots the projection to a plane, the shadow of the knot, characterizes the link/knot and allows to deduce link and knot invariants purely combinatorially by gradually removing the intersection points and writing a contribution to the link invariant determined by the orientations of intersecting strands and by which of them is above the other. Thus also the generalization of knot and link diagrams is of interest.

Linking of m- and n-dimensional sub-manifolds of D-dimensional manifold H_D occurs when the condition $m+n=D-1$ holds true. The n-dimensional sub-manifold intersects $m+1$-dimensional surfaces having m-dimensional manifold as its boundary at discrete points, and it is usually not possible to remove these points by deforming the surfaces without intersections in some intermediate stage. The generalization of the link diagram results as a projection $D-1$-dimensional disk D^{D-1} of H_D.

3-surfaces link in dimension $D=7$ so that the linking of 3-surfaces occurs quite generally in time=constant section of the embedding space. A link diagram would result as a projection to $E^2 \times CP_2$, E^2 a 2-dimensional plane: putting CP_2 coordinates constant gives ordinary link diagram in E^2. For magnetic flux tubes the reduction to 2-dimensional linking by idealizing flux tubes with 1-dimensional strings makes sense.

Knotting occurs in codimension 2 that is for an n-manifold imbedded in $D=n+2$-dimensional manifold. Knotting can be understood as follows. Knotted surface spans locally $n+1$-dimensional 2-sided n+1-disk D^{n+1} (disk for ordinary knot). The portion of surface going through D^{n+1} can be idealized with a 1-dimensional thread going through it and by $n+2=D$ knotting is locally linking of this 1-dimensional thread with n-dimensional manifold. N-dimensional knots define n+1-dimensional knots by so called spinning. Take an n-knot with the topology of sphere S^n such that the knotted part is above $n+1$-plane of $n+2$-dimensional space R^{n+2} $(z \geq 0)$, cut off the part below plane $(z<0)$, introduce an additional dimension (t) and make a 2π rotation for the resulting knot in $z-t$ plane. The resulting manifold is a knotted S^{n+1}. The counterpart of the knot diagram would be a projection to $n+1$-dimensional sub-manifold, most naturally disk D^{n+1}, of the embedding space.

3-surfaces could become knotted under some conditions. Vacuum extremals correspond to 4-surfaces $X^4 \subset M^4_+ \times Y^2$ whereas the four-surfaces $X^4 \subset M^4_+ \times S^2$, S^2 homologically non-trivial geodesic sphere, define their own "sub-theory". In both cases 3-surfaces in time=constant section of embedding space can get knotted in the sense that un-knotting requires giving up the defining condition temporarily. The counterpart of the knot diagram is the projection to $E^2 \times X^2$, $X^2 = Y^2$ or S^2, where E^2 is plane of M^4_+. For constant values of CP_2 coordinates ordinary knot diagram would result. Reduction to ordinary knot diagrams would naturally occur for $D = 2$ magnetic flux tubes. The knotting occurs also for 4-surfaces themselves in $M^4_+ \times X^2$: knot diagram is now defined as projection to $E^3 \times X^2$.

3. Could the magnetic field topology of 3-manifold be able to mimic other 3-topologies?

In $D = 3$ case the topological charges associated with Kähler Chern-Simons term characterize the linking of the field lines of the Kähler gauge potential A. What $dA \wedge A \neq 0$ means that field lines are linked and it is not possible to define a coordinate varying along the field lines of A. This is impossible even locally since the $dA \wedge A \neq 0$ condition is equivalent with non existence of a scalar functions k and Φ such that $\nabla\Phi = kA$ guaranteeing that Φ would be the sought for global coordinate.

One can idealize the situation a little bit and think of a field configuration for which magnetic flux is concentrated at one-dimensional closed lines. The vector potential would in this case be simply $A = \nabla(k\Psi + l\Phi)$, where Ψ is an angle coordinate around the singular line and Φ a coordinate along the singular circle. In this idealized situation the failure to have a global coordinate would be due to the singularities of otherwise global coordinates along one-dimensional linked and knotted circles. The reason is that the field lines of A and B rotate helically around the singular circle and the points (x, y, z) with constant values of x, y are on a helix which becomes singular at z-axis. Since the replacement of a field configuration with a non-singular field configuration but having same field line topology does not affect the global field line topology, one might hope of characterizing the field topology by its singularities along linked and knotted circles also in the general case.

Just similar linked and knotted circles are used to construct 3-manifolds in the link surgery which would suggest that the singularities of the field line topology of X^3 code the non-trivial 3-topology resulting when the singularities are removed by link surgery. Physically the longitude defining the framing $a + nb$ would correspond to the field line of A making an $n2\pi$ twist along the singular circle. Meridian would correspond to a circle in the plane of B. The bi-framing necessitated by TQFT would have a physical interpretation in terms of the helical field lines of A and B rotating around the singular circle. At the level of fields the gluing operation would mean a gauge transformation such that the meridians would become the field lines of the gauge transformed A and being non-helical could be continued to the interior of the glued torus without singularities. Simple non-helical magnetic torus would be in question.

This means that the magnetic field patterns of a given 3-manifold could mimic the topologies of other 3-manifolds. The topological mimicry of this kind would be a very robust manner to represent information and might be directly relevant to TQC. For instance, the computation of topological invariants of 3-manifold Y^3 could be coded by the field pattern of X^3 representing the link surgery producing the 3-manifold from S^3, and the physical realization of TQC program could directly utilize the singularities of this field pattern. Topological magnetized flux tubes glued to the back-ground 3-surface along the singular field lines of A could provide the braiding.

This mimicry could also induce transitions to the new topology and relate directly to 3-manifold surgery performed by a physical system. This transition would quite concretely mean gluing of simple $D = 2$ magnetic flux tubes along their boundaries to the larger $D = 3$ space-time sheet from which similar flux tube has been cut away.

4. A connection with anyons?

There is also a possible connection with anyons. Anyons are thought to correspond to singularities of gauge fields resulting in a symmetry breaking of gauge group to a finite subgroup H and are associated with homotopically non-trivial loops of $C_n = ((R^2)^n - D)/S_n$ represented as elements of H. Could the singularities of gauge fields relate to the singularities of the link surgery so that the singularities would be more or less identifiable as anyons? Could N-branched anyons be identified in terms of framings $a + Nb$ associated with the gluing map? $D = 3$ solutions allow the so called contact structure [K17], which means a decomposition of the coordinates of CP_2 projection to a longitudinal coordinate s and a complex coordinate w. Could this decomposition generalize the notion of effective 2-dimensionality crucial for the notion of anyon?

5. What about Witten's quantal link invariants?

Witten's quantal link invariants define natural multiplicative factors of WCW spinor fields identifiable as representations of two 2-dimensional topological evolution. In Witten's approach these invariants are defined as functional averages of non-integrable phase factors associated with a given link in a given 3-manifold. TGD does not allow any natural functional integral over gauge field configurations for a fixed 3-surface unless one is willing to introduce fictive non-Abelian gauge fields. Although this is not a problem as such, the representation of the invariants in terms of inherent properties of the 3-surface or corresponding 4-surfaces would be highly desirable.

Functional integral representation is not the only possibility. Quantum classical correspondence combined with topological field quantization implied by the preferred extremal property generalizing Bohr rules to the field context gives hopes that the 3-surfaces themselves might be able to represent 3-manifold invariants classically. In $D = 3$ case the quantized exponents of Kähler-Chern-Simons action and $SU(2)_L$ Chern-Simons action could define 3-manifold invariants. These invariants would satisfy the obvious multiplicativity conditions and could correspond to the phase factors due to the framing dependence of Witten's invariants identifying the loops of surgery link as Wilson loops. These phase factors are powers of $U = exp(i2\pi c/24)$, where c is the central charge of the Virasoro representation defined by Kac Moody representation. One has $c = k \times dim(g)/(k + c_g/2)$, which gives $U = exp(i2\pi k/8(k + 2))$ for $SU(2)$. The dependence on k differs from what one might naïvely expect. For this reason, and also because the classical Wilson loops do not depend explicitly on k, the value of k appearing in Chern-Simons action should be fixed by the internal consistency and be a constant of Nature according to TGD. The guess is that k possesses the minimal value $k = 3$ allowing a universal modular functor for $SU(2)$ with $q = exp(i2\pi/5)$.

The loops associated with the topological singularities of the Kähler gauge potential (typically the center lines of helical field configurations) would in turn define natural Wilson loops, and since the holonomies around these loops are also topologically quantized, they could define invariants of 3-manifolds obtained by performing surgery around these lines. The behavior of the induced gauge fields should be universal near the singularities in the sense that the holonomies associated with the CP_2 projections of the singularities to CP_2 would be universal. This expectation is encouraged by the notion of quantum criticality in general and in particular, by the interpretation of $D = 3$ phase as a critical system analogous to spin glass.

The exponent of Chern-Simons action can explain only the phase factors due to the framing, which are usually regarded as an unavoidable nuisance. This might be however all that is needed. For the manifolds of type $X^2 \times S^1$ all link invariants are either equal to unity or vanish. Surgery would allow to build 3-manifold invariants from those of $S^2 \times S^1$. For instance, surgery gives the invariant $Z(S^3)$ in terms of $Z(S^2 \times S^1, R_i)$ and mapping class group action coded into the linking of the field lines.

Holonomies can be also seen as multi-valued $SU(2)_L$ gauge transformations and can be mapped to a multi-valued transformations in the $SU(2)$ subgroup of $SU(3)$ acting on 3-surface as a geometric transformations and making it multi-branched. This makes sense if the holonomies define a finite group so that the gauge transformation is finitely many-valued. This description might apply to the 3-manifold resulting in a surgery defined by the Wilson loops identifiable as branched covering of the initial manifold.

The construction makes also sense for the holonomies defined by the classical $SU(3)$ gauge fields defined by the projections of the isometry currents. Furthermore, the fact that any CP_2 Hamiltonian defines a conserved topological charge in $D = 3$ phase should have a deep significance. At the level of WCW geometry the finite-dimensional group defining Kac Moody algebra is replaced with the group of canonical transformations of CP_2. Perhaps one could extend the notion of Wilson loop for the algebra of canonical transformations of CP_2 so that the representations R_i of the gauge group would be replaced by matrix representations of the canonical algebra. That the trace of the identity matrix is infinite in this case need not be a problem since one can simply redefine the trace to have value one.

Braids as topologically quantized magnetic fields

$D = 3$ space-time sheets would define complex braiding structures with flux tubes possessing infinite number of topological charges characterizing the linking of field lines. The world lines of the quantum computing dancers could thus correspond to the flux tubes that can get knotted, linked, and braided. This idea conforms with the earlier idea that the various knotted and linked structures formed by linear bio-molecules define some kind of computer programs.

1. Boundaries of magnetic flux tubes as light-like 3-surfaces

Field equations for Kähler action are satisfied identically at boundaries if the boundaries of magnetic flux tubes (and space-time sheet in general) are light-like in the induced metric. In M^4_+ metric the flux tubes could look static structures. Light-likeness allows an interpretation of the boundary state either as a 3-dimensional quantum state or as a time-evolution of a 2-dimensional quantum state. This conforms with the idea that quantum computation is cognitive, self reflective process so that quantum state is about something rather than something. There would be no need to force particles to flow through the braid structure to build up time-like braid whereas for time-like boundaries of magnetic flux tubes a time-like braid results only if the topologically charged particles flow through the flux tubes with the same average velocity so that the length along flux tubes is mapped to time.

Using the terminology of consciousness theory, one could say that during quantum dance the dancers are in trance being entangled to a single macro-temporally coherent state which represents single collective consciousness, and wake up to individual dancers when the dance ends. Quantum classical correspondence suggests that the generation of bound state entanglement between dancers requires tangled flux tubes connecting the space-time sheets of anyons (braid of flux tubes again!): dancers share mental images whereas direct contact between magnetic flux tubes defining the braid is not necessary. The bound state entanglement between sub-systems of unentangled systems is made possible by the many-sheeted space-time. This kind of entanglement could be interpreted as entanglement not visible in scales of larger flux tubes so that the notion is natural in the philosophy based on the idea of length scale resolution.

2. How braids are generated?

The encoding of the program to a braid could be a mechanical process: a bundle of magnetic flux tubes with one end fixed would be gradually weaved to a braid by stretching and performing the needed elementary twists. The time to perform the braiding mechanically requires classical computer program and the time needed to carry out the braiding depends polynomially on the number of strands.

The process could also occur by a quantum jump generating the braided flux tubes in single flash and perhaps even intentionally in living systems (flux tubes with negative topological charge could have negative energy so that it would require no energy to generate the structure from vacuum). The interaction with environment could be used to select the desired braids. Also ensembles of braids might be imagined. Living matter might have discovered this mechanism and used int intentionally.

3. Topological quantization, many-sheetedness, and localization

Localization of modular functors is one of the key problems in topological quantum computation (see the article of Freedman [B40]. For anyonic computation this would mean in the ideal case a decomposition of the system into batches containing 4 anyons each so that these anyon groups interact only during swap operations.

The role of topological quantization would be to select of a portion of the magnetic field defining the braid as a macroscopic structure. Topological field quantization realizes elegantly the requirement that single particle time evolutions between swaps involve no interaction with other anyons.

Also many-sheetedness is important. The (AA) pair and two anyons would correspond braids inside braids and as it turns out this gives more flexibility in construction of quantum computation since the 1-gates associated with logical qubits of 4-batch can belong to different representation of braid group than that associated with braiding of the batches.

2.4.2 Quantum Hall Effect And Fractional Charges In TGD

In fractional QH effect anyons possess fractional electromagnetic charges. Also fractional spin is possible. TGD explains fractional charges as being due to multi-branched character of space-time sheets. Also the Z_n-valued topological charge associated with anyons has natural explanation.

Basic TGD inspired ideas about quantum Hall effect

Quantum Hall effect is observed in low temperature systems when the intensity of a strong magnetic field perpendicular to the current carrying slab is varied adiabatically. Classically quantum Hall effect can be understood as a generation of a transversal electric field, which exactly cancels the magnetic Lorentz force. This gives $E = -j \times B/ne$. The resulting current can be also understood as due to a drift velocity proportional to $E \times B$ generated in electric and magnetic fields orthogonal to each other and allowing to cancel Lorentz force. This picture leads to the classical expression for transversal Hall conductivity as $\sigma_{xy} = ne/B$. σ_{xy} should vary continuously as a function of the magnetic field and 2-dimensional electron density n.

In quantum Hall effect σ_{xy} is piece-wise constant and quantized with relative precision of about 10^{-10}. The second remarkable feature is that the longitudinal conductivity σ_{xx} is very high at plateaus: variations by 13 orders of magnitude are observed. The system is also very sensitive to small perturbations.

Consider now what these qualitative observations might mean in TGD context.

1. Sensitivity to small perturbations means criticality. TGD Universe is quantum critical and quantum criticality reduces to the spin glass degeneracy due to the enormous vacuum degeneracy of the theory. The $D = 2$ and $D = 3$ non-vacuum phases predicted by the generalized Beltrami ansatz are this in-stability might play important role in the effect.

2. The magnetic fields are genuinely classical fields in TGD framework, and for $D = 2$ proportional to induced Kähler magnetic field. The canonical symmetries of CP_2 act like $U(1)$ gauge transformations on the induced gauge field but are not gauge symmetries since canonical transformations change the shape of 3-surface and affect both classical gravitational fields and electro-weak and color gauge fields. Hence different gauges for classical Kähler field represent magnetic fields for which topological field quanta can have widely differing and physically non-equivalent shapes. For instance, tube like quanta act effectively as insulators whereas magnetic walls parallel to the slab act as conducting wires.

   Wall like flux tubes parallel to the slab perhaps formed by a partial fusion of magnetic flux tubes along their boundaries would give rise to high longitudinal conductivity. For disjoint flux tubes the motion would be around the flux tubes and the electrons would get stuck inside these tubes. By quantum criticality and by $D < 4$ property the magnetic flux tube structures are unstable against perturbations, in particular the variation of the magnetic field strength itself. The transitions from a plateau to a new one would correspond to the decay of the magnetic walls back to disjoint flux tubes followed by a generation of walls again so that conductivity is very high outside transition regions. The variation of any parameter, such as temperature, is expected to be able to cause similar effects implying dramatic changes in Hall conductivity.

   The percolation model for the quantum Hall effect represents slab as a landscape with mountains and valleys and the varied external parameter, say B or free electron density, as the sea level. For the critical values of sea level narrow regions carrying so called edge states allow liquid to fill large regions appear and implies increase of conductivity. Obviously percolation model differs from the model based on criticality for which the landscape itself is highly fragile and a small perturbation can develop new valleys and mountains.

3. The effective 2-dimensionality implies that the solutions of Schrödinger equation of electron in external magnetic field are products of any analytic function with a Gaussian representing the ground state of a harmonic oscillator. Analyticity means that the kinetic energy is completely degenerate for these solutions. The Lauhglin ansatz for the state functions of electron in the external magnetic field is many-electron generalization of these solutions: the

wave functions consists of products of terms of form $(z_i - z_j)^m$, m odd integer from Fermi statistics.

The N-particle variant of Laughlin's ansatz allows to deduce that the system is incompressible. The key observation is that the probability density for the many-particle state has an interpretation as a Boltzmann factor for a fictive two-dimensional plasma in electric field created by constant charge density [D17, D14]. The probability density is extremely sensitive to the changes of the positions of electrons giving rise to the constant electron density. The screening of charge in this fictive plasma implies the filling fraction $\nu = 1/m$, m odd integer and requires charge fractionization $e \to e/m$. The explanation of the filling fractions $\nu = N/m$ would require multi-valued wave functions $(z_i - z_j)^{N/m}$. In single-sheeted space-time this leads to problems. TGD suggests that these wave functions are single valued but defined on N-branched surface.

The degeneracy with respect to kinetic energy brings in mind the spin glass degeneracy induced by the vacuum degeneracy of the Kähler action. The Dirac equation for the induced spinors is not ordinary Dirac equation but super-symmetrically related to the field equations associated with Kähler action. Also it allows vacuum degeneracy. One cannot exclude the possibility that also this aspect is involved at deeper level.

4. The fractionization of charge in quantum Hall effect challenges the idea that charged particles of the incompressible liquid are electrons and this leads to the notion of anyon. Quantum-classical correspondence inspires the idea that although dissipation is absent, it has left its signature as a track associated with electron. This track is magnetic flux tube surrounding the classical orbit of electron and electron is confined inside it. This reduces the dissipative effects and explains the increase of conductivity. The rule that there is single electron state per magnetic flux quantum follows if Bohr quantization is applied to the radii of the orbits. The fractional charge of anyon would result from a contribution of classical Kähler charge of anyon flux tube to the charge of the anyon. This charge is topologized in $D = 3$ phase.

Anyons as multi-branched flux tubes representing charged particle plus its track

Electrons (in fact, any charged particles) moving inside magnetic flux tubes move along circular paths classically. The solutions of the field equations with vanishing Lorentz 4-force correspond to asymptotic patterns for which dissipation has already done its job and is absent. Dissipation has however definite effects on the final state of the system, and one can argue that the periodic motion of the charged particle has created what might called its "track". The track would be realized as a circular or helical flux tube rotating around field lines of the magnetic field. The corresponding cyclotron states would be localized inside tracks. Simplest tracks are circular ones and correspond to absence of motion in the direction of the magnetic field. Anyons could be identified as systems formed as particles plus the tracks containing them.

1. Many-branched tracks and approach to chaos

When the system approaches chaos one expects the periodic circular tracks become non-periodic. One however expects that this process occurs in steps so that the tracks are periodic in the sense that they close after N 2π rotations with the value of N increasing gradually. The requirement that Kähler energy stays finite suggests also this. A basic example of this kind of track is obtained when the phase angles Ψ and Φ of complex CP_2 coordinates (ξ^1, ξ^2) have finitely multi-valued dependence on the coordinate ϕ of cylindrical coordinates: $(\Psi, \Phi) = (m_1/N, m_2/N)\phi)$. The space-sheet would be many-branched and it would take N turns of 2π to get back to the point were one started. The phase factors behave as a phase of a spinning particle having effective fractional spin $1/N$. I have proposed this kind of mechanism as an explanation of so called hydrino atoms claimed to have the spectrum of hydrogen atom but with energies scaled up by N^2 [K103] , [D9]. The first guess that N corresponds to m in $\nu = 1/m$ is wrong. Rather, N corresponds to N in $\nu = N/m$ which means many-valued Laughlin wave functions in single branched space-time.

Similar argument applies also in CP_2 degrees of freedom. Only the N-multiples of 2π rotations by CP_2 isometries corresponding to color hyper charge and color iso-spin would affect trivially the point of multi-branched surface. Since the contribution of Kähler charge to electromagnetic charge corresponds also to anomalous hyper-charge of spinor field in question, an additional geometric contribution to the anomalous hypercharge would mean anomalous electromagnetic charge.

It must be emphasized the fractionization of the isometry charges is only effective and results from the interpretation of isometries as space-time transformations rather than transformation rotating entire space-time sheet in embedding space. Also classical charges are effectively fractionized in the sense that single branch gives in a symmetric situation a fraction of $1/n$ of the entire charge. Later it will be found that also a genuine fractionization occurs and is due to the classical topologized Kähler charge of the anyon track.

2. Modelling anyons in terms of gauge group and isometry group

Anyons can be modelled in terms of the gauge symmetry breaking $SU(2)_L \rightarrow H$, where H is discrete sub-group. The breaking of gauge symmetry results by the action of multi-valued gauge transformation $g(x)$ such that different branches of the multi-valued map are related by the action of H.

1. The standard description of anyons is based on spontaneous symmetry breaking of a gauge symmetry G to a discrete sub-group H dynamically [A21]. The gauge field has suffered multi-valued gauge transformation such that the elements of H permute the different branches of $g(x)$. The puncture is characterized by the element of the H associated with the loop surrounding puncture. In the idealized situation that gauge field vanishes, the parallel translation of a particle around puncture affects the particle state, itself a representation of G, by the element of the homotopy $\pi_1(G/H) = H$ identifiable as non-Abelian magnetic charge. Thus holonomy group corresponds to homotopy group of G/H which in turn equals to H. This in turn implies that the infinite-dimensional braid group whose elements define holonomies in turn is represented in H.

2. In TGD framework the multi-valuedness of $g(x)$ corresponds to a many-branched character of 4-surface. This in turn induces a branching of both magnetic flux tube and anyon tracks describable in terms of $H \subset SU(2)_L$ acting as an isotropy group for the boundaries of the magnetic flux tubes. H can correspond only to a non-Abelian subgroup $SU(2)_L$ of the electro-weak gauge group for the induced (classical) electro-weak gauge fields since the Chern-Simons action associated with the classical color gauge fields vanishes identically. The electro-weak holonomy group would reduce to a discrete group H around loops defined by anyonic flux tubes surrounding magnetic field lines inside the magnetic flux tubes containing anyons. The reduction to H need to occur only at the boundaries of the space-time sheet where conducting anyons would reside: boundaries indeed correspond to asymptotia in well-defined sense. Electro-weak symmetry group can be regarded as a sub-group of color group of isometries in a well-defined sense so that H can be regarded also as a subgroup of color group acting as isotropies of the multi-branched surface at least in the in regions where gauge field vanishes.

3. For branched surfaces the points obtained by moving around the puncture correspond in a good approximation to some elements of $h \in H$ leading to a new branch but the 2-surface as a whole however remains invariant. The braid group of the punctured 2-surface would be also now represented as transformations of H. The simplest situation is obtained when H is a cyclic group Z_N of the $U(1)$ group of CP_2 geodesic in such a way that 2π rotation around symmetry axis corresponds to the generating element $exp(i2\pi/N)$ of Z_N.

   Dihedral group D_n having order $2n$ and acting as symmetries of n-polygon of the plane is especially interesting candidate for H. For $n = 2$ the group is Abelian group $Z_2 \times Z_2$ whereas for $n > 2$ D_n is a non-Abelian sub-group of the permutation group S_n. The cyclic group Z_4 crucial for TQC is a sub-group of D_4 acting as symmetries of square. D_4 has a 2-dimensional faithful representation. The numbers of elements for the conjugacy classes are 1, 1, 2, 2, 2. The sub-group commuting with a fixed element of a conjugacy class is D_4 for the 1-element conjugacy classes and cyclic group Z_4 for 2-element conjugacy classes. Hence 2-valued magnetic flux would be accompanied by Z_4 valued "electric charge" identifiable as a cyclic group permuting the branches.

3. Can one understand the increase in conductivity and filling fractions at plateaus?

Quantum Hall effect involves the increase of longitudinal conductivity by a factor of order 10^{13} [D17]. The reduction of dissipation could be understood as being caused by the fact that anyonic electrons are closed inside the magnetic flux tubes representing their tracks so that their interactions with matter and thus also dissipation are reduced.

Laughlin's theory [D17, D14] gives almost universal description of many aspects of quantum Hall effect and the question arises whether Laughlin's wave functions are defined on possibly multi-branched space-time sheet X^4 or at projection of X^4 to M^4_+. Since most theoreticians that I know still live in single sheeted space-time, one can start with the most conservative assumption that they are defined at the projection to M^4_+. The wave functions of one-electron state giving rise filling fraction $\nu = 1/m$ are constructed of $(z_i - z_j)^m$, where m is odd by Fermi statistics.

Also rational filling fractions of form $\nu = 1/m = N/n$ have been observed. These could relate to the presence of states whose projections to M^4 are multi-valued and which thus do not have any "classical" counterpart. For N-branched surface the single-valued wave functions $(\xi_i - \xi_j)^n$, n odd by Fermi statistics, correspond to apparently multi-valued wave functions $(z_i - z_j)^{n/N}$ at M^4 projection with fractional relative angular momenta $m = n/N$. The filling fraction would be $\nu = N/n$, n odd. All filling fractions reported in [D17] have n odd with n varying in the range $1-7$. N has the values $1, 2, 3, 4, 5, 7, 9$. Also values $N = 12, 13$ for which $n = 5$ are reported [B23].

The filling fractions $\nu = N/n = 5/2, 3/8, 3/10$ reported in [D18] would require even values of n conflicting with Fermi statistics. Obviously Lauhglin's model fails in this case and the question is whether one these fractions could correspond to bosonic anyons, perhaps Cooper pairs of electrons inside track flux tubes. The Z_N valued charge associated with N-branched surfaces indeed allows the maximum $2N$ electrons per anyon. Bosonic anyons are indeed the building block of the TQC model of [B23]. The anyon Cooper pairs could be this kind of states and their BE condensation would make possible genuine super-conductivity rather than only exceptionally high value of conductivity.

One can imagine also more complex multi-electron wave functions than those of Laughlin. The so called conformal blocks representing correlation functions of conformal quantum field theories are natural candidates for the wave functions [D13] and they appear naturally as state functions of in topological quantum field theories. For instance, wave functions which are products of factors $(z^k - z^l)^2$ with the Pfaffian $Pf(A_{kl})$ of the matrix $A_{kl} = 1/(z_k - z_l)$ guaranteeing anti-symmetrization have been used to explain even values of m [D13].

4. N-branched space-time surfaces make possible Z_N valued topological charge

According to [D13] that $2n$ non-Abelian anyon pairs with charge $1/4$ created from vacuum gives rise to a 2^{n-1}-fold degenerate ground state. It is also argued that filling fraction $5/2$ could correspond to this charge [B23]. TGD suggests somewhat different interpretation. 4-fold branching implies automatically the Z_4-valued topological charge crucial for anyonic quantum computation. For 4-branched space-time surface the contribution of a single branch to electron's charge is indeed $1/4$ units but this has nothing to do with the actual charge fractionization. The value of ν is of form $\nu = /m$ and electromagnetic charge equals to $\nu = 4e/m$ in this kind of situation.

If anyons (electron plus flux tube representing its track) have Z_4 charges 1 and 3, their Cooper pairs have charges 0 and 2. The double-fold degeneracy for anyon's topological charge means that it possesses topological spin conserved modulo 4. In presence of $2n$ anyon pairs one would expect 2^n-fold degeneracy. The requirement that the net topological charge vanishes modulo 4 however fixes the topological charge of n: th pair so that 2^{n-1} fold degeneracy results.

A possible interpretation for Z_N-valued topological charge is as fractional angular momenta k/N associated with the phases $exp(ik2\pi/N)$, $k = 0, 1, ..., n-1$ of particles in multi-branched surfaces. The projections of these wave functions to single-branched space-time would be many-valued. If electro-weak gauge group breaks down to a discrete subgroup H for magnetic flux tubes carrying anyonic "tracks", this symmetry breakdown could induce their multi-branched property in the sense rotation by 2π would correspond to H isometry leading to a different branch.

Topologization of Kähler charge as an explanation for charge fractionization

The argument based on what happens when one adds one anyon to the anyon system by utilizing Faraday's law [D17] leads to the conclusion that anyon charge is fractional and given by νe. The anyonic flux tube along boundary of the flux tube corresponds to the left hand side in the Faraday's equation

$$\oint E \cdot dl = -\frac{d\Phi}{dt} \ .$$

By expressing E in turns of current using transversal conductivity and integrating with respect to time, one obtains

$$Q = \nu e$$

for the charge associated with a single anyon. Hence the addition of the anyon means an addition of a fractional charge νe to the system. This argument should survive as such the 1-branched situation so that at least in this case the fractional charges should be real.

In N-branched case the closed loop $\oint E \cdot dl$ around magnetic flux tube corresponds to N-branched anyon and surrounds the magnetic flux tube N times. This would suggest so that net magnetic flux should be N times the one associated with single but unclosed 2π rotation. Hence the formula would seem to hold true as such also now for the total charge of the anyon and the conclusion is that charge fractionization is real and cannot be an effective effect due to fractionization of charge at single branch of anyon flux tube.

One of the basic differences between TGD and Maxwell's theory is the possibility of vacuum charges and this provides an explanation of the effect is in terms of vacuum Kähler charge. Kähler charge contributes $e/2$ to the charge of electron. Anyon flux tube can generate vacuum Kähler charge changing the net charge of the anyon. If the anyon charge equals to νe the conclusions are following.

1. The vacuum Kähler charge of the anyon track is $q = (\nu - 1)e$.

2. The dimension of the CP_2 projection of the anyon flux tube must be $D = 3$ since only in this case the topologization of anyon charge becomes possible so that the charge density is proportional to the Chern-Simons term $A \wedge dA/4\pi$. Anyon flux tubes cannot be super-conducting in the sense that non-integrable phase factor $exp(\int A{\cdot}dl)$ would define global order parameter. The boundaries of anyonic flux tubes could however remain potentially super-conducting and anyon Cooper pairs would be expelled there by Meissner effect. This gives super-conductivity in length scale of single flux tube. Conductivity and super-conductivity in long length scales requires that magnetic flux tubes are glued together along their boundaries partially.

3. By Bohr quantization anyon tracks can have $r_n = \sqrt{n} \times r_B$, $n \leq m$, where r_m corresponds to the radius of the magnetic flux tube carrying m flux quanta. Only the tracks with radius r_m contribute to boundary conductivity and super-conductivity giving $\nu = 1/m$ for singly branched surfaces.

   The states with $\nu = N/m$ cannot correspond to non-super-conducting anyonic tracks with radii r_n, $n < m$, n odd, since these cannot contribute to boundary conductivity. The many-branched character however allows an N-fold degeneracy corresponding to the fractional angular momentum states $exp(ik\phi/N)$, $k = 0, ..., N-1$ of electron inside anyon flux tubes of radius r_m. k is obviously a an excellent candidate for the Z_N-valued topological charge crucial for anyonic quantum computation. Z_4 is uniquely selected by the braid matrix R.

   Only part of the anyonic Fermi sea need to be filled so that filling fractions $\nu = k/m$, $k = 1, ..., N$ are possible. Charges νe are possible if each electron inside anyon track contributes $1/m$ units to the fractional vacuum Kähler charge. This is achieved if the radius of the anyonic flux tube grows as $\sqrt{k/m}$ when electrons are added. The anyon tracks containing several electrons give rise to composite fermions with fermion number up to $2N$ if both directions of electron spin are allowed.

4. Charge fractionization requires vacuum Kähler charge has rational values $Q_K = (\nu - 1)e$. The quantization indeed occurs for the helicity defined by Chern-Simons term $A \wedge dA/4\pi$. For compact 3-spaces without boundary the helicity can be interpreted as an integer valued invariant characterizing the linking of two disjoint closed curves defined by the magnetic field

lines. This topological charge can be also related to the asymptotic Hopf invariant proposed by Arnold [B49], which in non-compact case has a continuum of values. Vacuum Kähler current is obtained from the topological current $A \wedge dA/4\pi$ by multiplying it with a function of CP_2 coordinates completely fixed by the field equations. There are thus reasons to expect that vacuum Kähler charge and also the topological charges obtained by multiplying Chern Simons current by $SU(3)$ Hamiltonians are quantized for compact 3-surfaces but that the presence of boundaries replaces integers by rationals.

What happens in quantum Hall system when the strength of the external magnetic field is increased?

The proposed mechanism of anyonic conductivity allows to understand what occurs in quantum Hall system when the intensity of the magnetic field is gradually increased.

1. Percolation picture encourages to think that magnetic flux tubes fuse partially along their boundaries in a transition to anyon conductivity so that the anyonic states localized at the boundaries of flux tubes become de-localized much like electrons in metals. Laughlin's states provide an idealized description for these states. Also anyons, whose tracks have Bohr radii r_m smaller than the radius r_B of the magnetic flux tube could be present but they would not participate in this localization. Clearly, the anyons at the boundaries of magnetic flux tubes are highly analogous to valence electrons in atomic physics.

2. As the intensity of the magnetic field B increases, the areas a of the flux tubes decreases as $a \propto 1/B$: this means that the existing contacts between neighboring flux tubes tend to be destroyed so that anyon conductivity is reduced. On the other hand, new magnetic flux tubes must emerge by the constancy of the average magnetic flux implying $dn/da \propto B$ for the average density of flux tubes. This increases the probability that the newly generated flux tubes can partially fuse with the existing flux tubes.

3. If the flux tubes are not completely free to move and change their shape by area preserving transformations, one can imagine that for certain value ranges of B the generation of new magnetic flux tubes is not favored since there is simply no room for the newcomers. The Fermi statistics of the anyonic electrons at the boundaries of flux tubes might relate to this non-hospitable behavior. At certain critical values of the magnetic field the sizes of flux tubes become however so small that the situation changes and the new flux tubes penetrate the system and via the partial fusion with the existing flux tubes increase dramatically the conductivity.

Also protonic anyons are possible

According to the TGD based model, any charged particle can form anyons and the strength of the magnetic field does not seem to be crucial for the occurrence of the effect and it could occur even in the Earth's magnetic field. The change of the cyclotron and Larmor frequencies of the charged particle in an external magnetic field to a value corresponding to the fractional charge provides a clear experimental signature for both the presence of anyons and for their the fractional charge.

Interestingly, water displays a strange scaling of proton's cyclotron frequency in an external magnetic field [D15] , [J26]. In an alternating magnetic field of.1551 Gauss (Eearth's field has a nominal value of.58 Gauss) a strong absorption at frequency $f = 156$ Hz was observed. The frequency was halved when D_2O was used and varied linearly with the field strength. The resonance frequency however deviated from proton's Larmor frequency, which suggests that a protonic anyon is in question. The Larmor frequency would be in this case $f_L = r \times \nu eB/2m_p$, where $r = \mu_p/\mu_B = 2.2792743$ is the ratio of proton's actual magnetic moment to its value for a point like proton. The experimental data gives $\nu = .6003 = 3/5$ with the accuracy of 5×10^{-4} so that 3-branched protonic anyons with $m = 5$ would be responsible for the effect.

If this interpretation is correct, entire p-adic hierarchy of anyonic NMR spectroscopies associated with various atomic nuclei would become possible. Bosonic anyon atoms and Cooper pairs of fermionic anyon atom could also form macroscopic quantum phases making possible superconductivity very sensitive to the value of the average magnetic field and bio-systems and brain could utilize this feature.

2.4.3 Does The Quantization Of Planck Constant Transform Integer Quantum Hall Effect To Fractional Quantum Hall Effect?

The model for topological quantum computation inspired the idea that Planck constant might be dynamical and quantized. The work of Nottale [E1] gave a strong boost to concrete development of the idea and it took year and half to end up with a proposal about how basic quantum TGD could allow quantization Planck constant associated with M^4 and CP_2 degrees of freedom such that the scaling factor of the metric in M^4 degrees of freedom corresponds to the scaling of $\hbar$ in CP_2 degrees of freedom and vice versa [K36]. The dynamical character of the scaling factors of M^4 and CP_2 metrics makes sense if space-time and embedding space, and in fact the entire quantum TGD, emerge from a local version of an infinite-dimensional Clifford algebra existing only in dimension $D = 8$ [K110].

The predicted scaling factors of Planck constant correspond to the integers n defining the quantum phases $q = exp(i\pi/n)$ characterizing Jones inclusions. A more precise characterization of Jones inclusion is in terms of group $G_b \subset SU(2) \subset SU(3)$ in CP_2 degrees of freedom and $G_a \subset SL(2,C)$ in M^4 degrees of freedom. In quantum group phase space-time surfaces have exact symmetry such that to a given point of M^4 corresponds an entire G_b orbit of CP_2 points and vice versa. Thus space-time sheet becomes $N(G_a)$ fold covering of CP_2 and $N(G_b)$-fold covering of M^4. This allows an elegant topological interpretation for the fractionization of quantum numbers. The integer n corresponds to the order of maximal cyclic subgroup of G.

In the scaling $\hbar_0 \rightarrow n\hbar_0$ of M^4 Planck constant fine structure constant would scale as

$$\alpha = \frac{e^2}{4\pi\hbar c} \rightarrow \frac{\alpha}{n} \ ,$$

and the formula for Hall conductance would transform to

$$\sigma_H \rightarrow \frac{\nu}{n}\alpha \ .$$

Fractional quantum Hall effect would be integer quantum Hall effect but with scaled down α. The apparent fractional filling fraction $\nu = m/n$ would directly code the quantum phase $q = exp(i\pi/n)$ in the case that m obtains all possible values. A complete classification for possible phase transitions yielding fractional quantum Hall effect in terms of finite subgroups $G \subset SU(2) \subset SU(3)$ given by ADE diagrams would emerge (A_n, D_{2n}, E_6 and E_8 are possible). What would be also nice that CP_2 would make itself directly manifest at the level of condensed matter physics.

2.4.4 Why 2+1-Dimensional Conformally Invariant Witten-Chern-Simons Theory Should Work For Anyons?

Wess-Zumino-Witten theories are 2-dimensional conformally invariant quantum field theories with dynamical variables in some group G. The action contains the usual 2-dimensional kinetic term for group variables allowing conformal group action as a dynamical symmetry plus winding number defined associated with the mapping of 3-surface to G which is $Diff^4$ invariant. The coefficient of this term is quantized to integer.

If one couples this theory to a gauge potential, the original chiral field can be transformed away and only a Chern-Simons term defined for the 3-manifold having the 2-dimensional space as boundary remains. Also the coefficient k of Chern-Simons term is quantized to integer. Chern-Simons-Witten action has close connection with Wess-Zumino-Witten theory. In particular, the states of the topological quantum field theory are in one-one correspondence with highest weights of the WZW action.

The appearance of 2+1-dimensional $Diff^3$ invariant action can be understood from the fundamentals of TGD.

1. Light-like 3-surfaces of both future light-cone M^4_+ and of space-time surface X^4 itself are in a key role in the construction of quantum TGD since they define causal determinants for Kähler action.

2. At the space-time level both the boundaries of X^4 and elementary particle horizons surrounding the orbits of wormhole contacts define light-like 3-surfaces. The field equations are

satisfied identically at light-like boundaries. Of course, the projections of the the light-like surfaces of X^4 to Minkowski space need not look light-like at all, and even boundaries of magnetic flux tubes could be light-like.

Light-like 3-surfaces are metrically 2-dimensional and allow a generalized conformal invariance crucial for the construction of quantum TGD. At the level of embedding space conformal super-symplectic invariance results. At the space-time level the outcome is conformal invariance highly analogous to the Kac Moody symmetry of super string models [K25, K96]. In fact, there are good reasons to believe that the three-dimensional Chern-Simons action appears even in the construction of configuration space metric and give an additional contribution to the configuration space metric when the light-like boundaries of 3-surface have 3-dimensional CP_2 projection.

3. By the effective two-dimensionality the Wess-Zumino-Witten action containing Chern-Simons term is an excellent candidate for the quantum description of S-matrix associated with the light-like 3-surfaces since by the vanishing of the metric determinant one cannot define any general coordinate invariant 3-dimensional action other than Chern-Simons action. The boundaries of the braid formed by the magnetic flux tubes having light-like boundaries, perhaps having flux tubes between swapped flux tubes would define the 2+1-dimensional space-time associated with a braid, would define the arena of Witten-Chern-Simons theory describing anyons. This S-matrix can be interpreted also as characterizing either a 3-dimensional quantum state since light-like boundaries are limiting cases of space-like 3-surfaces.

4. Kähler action defines an Abelian Chern-Simons term and the induced electroweak gauge fields define a non-Abelian variant of this term. The Chern-Simons action associated with the classical color degrees of freedom vanishes as is easy to find. The classical color fields are identified as projections of Killing vector fields of color group: $A_\alpha^c = j_k^A \partial_\alpha s^k \tau_A = {J_k}^r \partial_r H^A \partial_\alpha s^k$. The classical color gauge field is proportional to the induced Kähler form: $F_{\alpha\beta}^c = H^A J_{\alpha\beta} \tau_A$. A little calculation shows that the instanton density vanishes by the identity $H_A H^A = 1$ (this identity is forced by the necessary color-singletness of the YM action density and is easy to check in the simpler case of S^2.

5. Since qubit realizes the fundamental representation of the quantum group $SU(2)_q$, $SU(2)$ is in a unique role concerning the construction of modular functors and quantum computation using Chern-Simons action. The quantum group corresponding to $q = exp(i2\pi/r)$, $r = 5$ is realized for the level $k = 3$ Chern-Simons action and satisfies the constraint $r = k + c_g$, where $c_g = 2$ is the so called dual Coxeter number of $SU(2)$ [B23, B28, B39].

   The exponent non-Abelian $SU(2)_L \times U(1)$ Chern-Simons action combined with the corresponding action for Kähler form so that effective reduction to $SU(2)_L$ occurs, could appear as a multiplicative factor of the WCW spinor fields defined in the WCW . Since 3-dimensional quantum state would represent a 2-dimensional time evolution the role of these phase factor would be very analogous to the role of ordinary Chern-Simons action.

2.5 Topological Quantum Computation In TGD Universe

The general philosophy behind TQC inspires the dream that the existence of basic gates, in particular the maximally entangling 2-gate R, is guaranteed by the laws of Nature so that no fine tuning would be needed to build the gates. Negentropy Maximization Principle, originally developed in context of TGD inspired theory of consciousness, is a natural candidate for this kind of Law of Nature.

2.5.1 Concrete Realization Of Quantum Gates

The bold dream is that besides 2-gates also 1-gates are realized by the basic laws of Nature. The topological realization of the 3-braid representation in terms of Temperley-Lie algebra allows the reduction of 1-gates to 2-gates.

NMP and TQC

Quantum jump involves a cascade of self measurements in which the system under consideration can be though of as decomposing to two parts which are either un-entangled or possess rational or extended rational entanglement in the final state. The sub-system is selected by the requirement that entanglement negentropy gain is maximal in the measurement of the density matrix characterizing the entanglement of the sub-system with its complement.

In the case case that the density matrix before the self measurement decomposes into a direct sum of matrices of dimensions N_i, such that $N_i > 1$ holds true for some values of i, say i_0, the final state is a rationally entangled and thus a bound state. i_0 is fixed by the requirement that the number theoretic entropy for the final state maximally negative and equals to $klog(p)$, where p^k is the largest power of prime dividing N_{i_0}. This means that maximally entangled state results and the density matrix is proportional to a unit matrix as it is also for the entanglement produced by R. In case of R the density matrix is $1/2$ times 2-dimensional unit matrix so that bound state entanglement negentropy is 1 bit.

The question is what occurs if the density matrix contains a part for which entanglement probabilities are extended rational but not identical. In this case the entanglement negentropy is positive and one could argue that no self-measurement occurs for this state and it remains entangled. If so then the measurement of the density matrix would occur only when it increases entanglement negentropy. This looks the only sensible option since otherwise only bound state entanglement with identical entanglement probabilities would be possible. This question is relevant also because Temperley-Lieb representation using $(AA)-A-A$ system involves entanglement with entanglement probabilities which are not identical.

In the case that the 2-gate itself is not directly entangling as in case of R' and R'', NMP should select just the quantum history, that single particle gates at it guarantee maximum entanglement negentropy. Thus NMP would come in rescue and give hopes that various gates are realized by Nature.

Non-Abelian anyon systems are modelled in terms of punctures of plane and Chern-Simons action for the incompressible vector potential of hydrodynamical flow. It is interesting to find how these ideas relate to the TGD description.

Non-Abelian anyons reside at boundaries of magnetic flux tubes in TGD

In [B23] anyons are modelled in terms of punctures of plane defined by the slab carrying Hall current. In TGD the punctures correspond naturally to magnetic flux tubes defining the braid. It is now however obvious under what conditions the braid containing the TGD counterpart of (AA)-A-A system can be described as a punctured disk if the flux tubes describing the tracks of valence anyons are very near to the boundaries of the magnetic flux tubes. Rather, the punctured disk is replaced with the closed boundary of the magnetic flux tube or of the structure formed by the partial fusion of several magnetic flux tubes. This microscopic description and is consistent with Laughlin's model only if it is understood as a long length scale description.

Non-Abelian charges require singularities and punctures but a two-surface which is boundary does not allow punctures. The punctures assigned with an anyon pair would become narrow wormhole threads traversing through the interior of the magnetic flux tube and connecting the punctures like wormholes connect two points of an apple. It is also possible that the threads connect the surfaces of two nearby magnetic flux tubes. The wormhole like character conforms with the fact that non-Abelian anyons appear always in pairs.

The case in which which the ends of the wormhole thread belong to different neighboring magnetic flux tubes, call them T_1 and T_2, is especially interesting as far as the model for TQC is considered. The state of $(AA) - A - A$ system before (after) the 3-braid operation would be identifiable as anyons near the surface of T_1 (T_2). If only sufficiently local operations are allowed, the braid group would be same as for anyons inside disk. This means consistency with the anyon model of [B23] for TQC requiring that the dimension for the space of ground states is 2^{n-1} in a system consisting of n anyon pairs.

The possibility of negative energies allows inspires the idea that the anyons at T_2 have negative energies so that the anyon system would have a vanishing net energy. This would conform with the idea that the scattering from initial to final state is equivalent with the creation of zero energy state for which initial (final) state particles have positive (negative) energies, and with the fact that the boundaries of magnetic flux tubes are light-like systems for which 3-D quantum state is representation for a 2-D time evolution.

Since the correlation between anyons at the ends of the wormhole thread is purely topological, the most plausible option is that they behave as free anyons dynamically. Assuming 4-branched anyon surfaces, the charges of anyons would be of form $Q = \nu_A e$, $\nu_A = 4/m$, m odd.

Consider now the representation of 3-braid group. That the mapping class group for the 3-braid system should have a 2-dimensional representation is obvious from the fact that the group has same generators as the mapping class group for torus which is represented by as $SL(2,Z)$ matrices acting on the homology of torus having two generators a, b corresponding to the two non-contractible circles around torus. 3-braid group would be necessarily represented in Temperley-Lieb representation.

The character of the anyon bound state is important for braid representations.

1. If anyons form loosely bound states (AA), the electrons are at different tracks and the charge is additive in the process so that one has $Q_{AA} = 2Q_A = 8/m$, m odd, which is at odds with statistics. It might be that the naïve rule of assigning fractional charge to the state does not hold true for loosely bound bosonic anyons. In this case $(AA) - A$ system with charge states $((1,-1),1)$ and $((1,1),-1)$ would be enough for realizing 1-gates in TQC. The braid operation s_2 of Temperley-Lieb representation represented $(A_1A_2)-A_3 \rightarrow (A_1A_3)-A_2$ would correspond to an exchange of the dance partner by a temporary decay of (A_1A_2) followed by a recombination to a quantum superposition of (A_1A_2) and (A_1A_3) and could be regarded as an ordinary braid operation rather than monodromy. The relative phase 1-gate would correspond to s_1 represented as braid operation for A_1 and A_2 inside (A_1A_2).

2. If anyons form tightly bound states (AA) in the sense that single anyonic flux tube carries two electrons, charge need not be additive so that bound states could have charges $Q = 4/2m_1$ so that the vacuum Kähler charge $Q_K = 4(1/m_1 - 2/m)$ would be created in the process. This would stabilize (AA) state and would mean that the braid operation $(A_1A_2) - A_3 \rightarrow (A_1A_3) - A_2$ cannot occur via a temporary decay to free anyons and it might be necessary to replace 3-braid group by a partially colored 3-braid group for $(AA) - A - A$ system which is sub-group of 3-braid group and has generators s_1^2 (two swaps for $(AA) - A$) and s_2 (swap for $A - A$) instead of s_1 and s_2. Also in this case a microscopic mechanism changing the value of (AA) Z^4 charge is needed and the situation might reduce to the case a) after all.

   The Temperley Lieb representation for this group is obtained by simply taking square of the generator inducing entanglement (s_2 rather than s_1 in the notation used!). The topological charge assignments for $(AA)-A-A$ system are $((1,-1),1,-1)$ and $((1,1),-1,-1)$. s_1^2 would correspond to the group element generating $(AA) - A$ entanglement and s_2 acting on $A - A$ pair would correspond to phase generating group element.

Braid representations and 4-branched anyon surfaces

Some comments about braid representations in relation to Z_N- valued topological charges are in order.

1. Yang-Baxter braid representation using the maximally entangling braid matrix R is especially attractive option. For anyonic computation with Z_4-valued topological charge R is the unique 2-gate conserving the net topological charge (note that the mixing of the $|1,1\rangle$ and $|-1,-1\rangle$ is allowed). On the other, R allows only the conservation of Z_4 value topological charge. This suggests that the entanglement between logical qubits represented by $(AA) - A - A$ batches is is generated by R. The physical implication is that only $\nu = 4/n$ 4-branched anyons could be used for TQC.

2. In TGD framework the entangling braid representation inside batches responsible for 1-gates need not be the same since batches correspond to magnetic flux tubes. In standard physics context it would be harder to defend this kind of assumption. As will be found 3-braid Temperley-Lieb representation is very natural for 1-gates. The implication is that the n-braid system with braids represented as 4-batches would have 2^n-dimensional space of logical qubits in fact identical with the space of realizable qubits.

3. Also n-braid Temperley-Lieb representations are possible and the explicit expressions of the braiding matrices for 6-braid case suggest that Z_4 topological charge is conserved also now [B28]. In this case the dimension of the space of logical qubits is for highly favored value of quantum group parameter $q = exp(i\pi/5)$ given by the Fibonacci number $F(n)$ for n-braid case and behaves as Φ^{4n} asymptotically so that this option would be more effective. From $\Phi^4 = 1 + 3\Phi \simeq 8.03$ one can say that single 4-batch carries 3 bits of information instead of one. This is as it must be since topological charge is not conserved inside batches separately for this option.

4. $(AA) - A$ representation based on Z_4-valued topological charge is unique in that the space of logical qubits would be the space of topologically realizable qubits. Quantum superposition of logical qubits could could be represented $(AA) - A$ entangled state of form $a|2, -1\rangle + b|0, 1\rangle$ generated by braid action. Relative phase could be generated by braid operation acting on the entangled state of anyons of (AA) Cooper pair. Since the superposition of logical cubits corresponds to an entangled state $a|2, -1\rangle + b|0, 1\rangle$ for which coefficients are extended rational numbers, the number theoretic realization of the bound state property could pose severe conditions on possible relative phases.

2.5.2 Temperley-Lieb Representations

The articles of Kaufmann [B36] and Freedman [B28, B40] provide enjoyable introduction to braid groups and to Tempeley-Lie representations. In the sequel Temperley-Lieb representations are discussed from TGD view point.

Temperley-Lieb representation for 3-braid group

In [B36] it is explained how the so called Temperley-Lie algebra defined by 2×2-matrices I, U_1, U_2 satisfying the relations $U_1^2 = dU_1$, $U_2^2 = dU_2$, $U_1U_2U_1 = U_2$, $U_2U_1U_2 = U_1$ allows a unitary representation of Artin's braid group by unitary 2×2 matrices. The explicit representations of the matrices U_1 and U_2 (note that U_i/d acts as a projector) given by

$$\begin{aligned} U_1 &= \begin{pmatrix} d & 0 \\ 0 & 0 \end{pmatrix} , \\ U_2 &= \begin{pmatrix} \frac{1}{d} & \sqrt{1-\frac{1}{d^2}} \\ \sqrt{1-\frac{1}{d^2}} & d-\frac{1}{d} \end{pmatrix} . \end{aligned} \tag{2.5.1}$$

Note that the eigenvalues of U_i are d and 0. The representation of the elements s_1 and s_2 of the 3-braid group is given by

$$\begin{aligned} \Phi(s_1) &= AI + A^{-1}U_1 = \begin{pmatrix} -U^{-3} & 0 \\ 0 & U \end{pmatrix} , \\ \Phi(s_2) &= AI + A^{-1}U_2 = \begin{pmatrix} -\frac{U^3}{d} & \frac{U^{-1}}{\sqrt{1-(1/d)^2}} \\ \frac{U^{-1}}{\sqrt{1-(1/d)^2}} & \frac{U^{-5}}{d} \end{pmatrix} , \\ U &= exp(i\phi) . \end{aligned} \tag{2.5.2}$$

Here the condition $d = -A^2 - A^{-2}$ is satisfied. For $A = exp(i\phi)$, with $|\phi| \leq \pi/6$ or $|\pi - \phi| \leq \pi/6$, the representation is unitary. The constraint comes from the requirement $d > 1$. From the basic representation it follows that the eigenvalues of $\Phi(s_i)$ are $-exp(-3i\phi)$ and $exp(i\phi)$.

Tihs 3-braid representation is a special case of a more general Temperley-Lieb-Jones representation discussed in [B28] using notations $A = \sqrt{-1}exp(-i2\pi/4r)$, $s = A^2$, and $q = A^4$. In this case all eigen-values of all representation matrices are -1 and $q = exp(-i2\pi/r)$. This representation results by multiplying Temperley-Lieb representation above with an over-all phase factor $exp(4i\phi)$ and by the replacement $A = exp(i\phi) \rightarrow \sqrt{-1}A$.

Constraints on the parameters of Temperley-Lieb representation

The basic mathematical requirement is that besides entangling 2-gate there is minimum set of 1-gates generating infinite sub-group of $U(2)$. Further conditions come from the requirement that a braid representation is in question. In the proposal of [B23, B28] the 1-gates are realized using Temperley-Lieb 3-braid representation. It is found that there are strong constraints to the representation and that relative phase gate generating the phase $exp(i\phi) = exp(i2\pi/5)$ is the simplest solution to the constraints.

The motivation comes from the findings made already by Witten in his pioneering work related to the topological quantum field theories and one can find a good representation about what is involve din [A24].

Topological quantum field theories can produce unitary modular functors when the $A = q^{1/4} = exp(i\phi)$ characterizing the quantum group multiplication is a root of unity so that the quantum enveloping algebra $U(Sl(2))_q$ defined as the quantum version of the enveloping algebra $U(Sl(2))$ is not homomorphic with $U(Sl(2))$ and theory does not trivialize. Besides this, q must satisfy some consistency conditions. First of all, $A^{4n} = 1$ must be satisfied for some value of n so that A is either a primitive l: th, $2l$: th of unity for l odd, or $4l$: th primitive root of unity.

This condition relates directly to the fact that the quantum integers $[n]_q = (A^{2n} - A^{-2n})/(A^2 - A^{-2})$ vanish for $n \geq l$ so that the representations for a highest weight n larger than l are not irreducible. This implies that the theory simplifies dramatically since these representations can be truncated away but can cause also additional difficulties in the definition of link invariants. Indeed, as Witten found in his original construction, the topological field theories are unitary for $U(Sl(2))_q$ only for $A = exp(ik\pi/2l)$, k not dividing $2l$, and $A = exp(i\pi/l)$, l odd (no multiples are allowed) [A24]. $n = 2l = 10$, which is the physically favored choice, corresponds to the relative phase $4\phi = 2\pi/5$.

Golden Mean and quantum computation

Temperley-Lieb representation based on $q = exp(i2\pi/5)$ is highly preferred physically.

1. One might hope that the Yang-Baxter representation based on maximally entangling braid matrix R might work. $R^8 = 1$ constraint is however not consistent with Temperley-Lieb representations. The reason is that $\Phi^8(s_1) = 1$ gives $\phi = \pi/4 > \pi/6$ so that unitarity constraint is not satisfied. $\phi = exp(i2\pi/16)$ corresponding $r = 4$ and to the matrix $\Phi(s_2) = \hat{R} = exp(i2\pi/16) \times R$ allows to satisfy the unitarity constraint. This would look like a very natural looking selection since $\Phi(s_2)$ would act as a Hadamard gate and NMP would imply identical entanglement probabilities if a bound state results in a quantum jump. Unfortunately, s_1 and s_2 do not generate a dense subgroup of $U(2)$ in this case as shown in [B28].

2. $\phi = \pi/10$ corresponding to $r = 5$ and Golden Mean satisfies all constraints coming from quantum computation and knot theory. That is it spans a dense subgroup of $U(2)$, and allows the realization of modular functor defined by Witten-Chern-Simons $SU(2)$ action for $k = 3$, which is physically highly attractive since the condition

$$r = k + c_g(SU(2))$$

connecting r, k and the dual Coxeter number $c_g(SU(N)) = n$ in WCS theories is satisfied for $SU(2)$ in this case for $r = 5$ and $k = 3$.

$SU(2)$ would have interpretation as the left-handed electro-weak gauge group $SU(2)_L$ associated with classical electro-weak gauge fields. The symmetry breaking of $SU(2)_L$ down to a discrete subgroup of $SU(2)_L$ yielding anyons would relate naturally to this. The conservation of the topologized Kähler charge would correlate with the fact that there is no symmetry breaking in the classical $U(1)$ sector. $k = 3$ Chern-Simons theory is also known to share the same universality class as simple 4-body Hamiltonian [B23] (larger values of k would correspond to $k + 1$-body Hamiltonians).

3. Number theoretical vision about intentional systems suggests that the preferred relative phases are algebraic numbers or more generally numbers which belong to a finite-dimensional extension of p-adic numbers. The idea about p-adic cognitive evolution as a gradual generation of increasingly complex algebraic extensions of rationals allows to see the extension containing Golden Mean $\Phi = (1+\sqrt{5})/2$ as one of the simplest extensions. The relative phase $exp(i4\phi) = exp(i2\pi/5)$ is expressible in an extension containing $\sqrt{\Phi}$ and Φ: one has $cos(4\phi) = (\Phi - 1)/2$ and $sin(4\phi) = \sqrt{5\Phi}/2$.

The general number theoretical ideas about cognition support the view that Golden Mean is in a very special role in the number theoretical world order. This would be due to the fact that $log(\Phi)/\pi$ is a rational number. This hypothesis would explain scaling hierarchies based on powers of Golden Mean. One could argue that the geometry of the braid should reflect directly the value of the $A = exp(i2\phi)$. The angle increment per single DNA nucleotide is $\phi/2 = 2\pi/10$ for DNA double strand (note that q would be $exp(i\pi/10)$, which raises the question whether DNA might be a topological quantum computer.

Bratteli diagram for $n = 5$ case, Fibonacci numbers, and microtubuli

Finite-dimensional von Neumann algebras can be conveniently characterized in terms of Bratteli diagrams [A27]. For instance, the diagram a) of the figure **??** at the end of the chapter represents the inclusion $N \subset M$, where $N = M_2(C) \otimes C$, $M = M_6(C) \otimes M_3(C) \otimes C$. The diagram expresses the embeddings of elements $A \otimes x$ of $M_2(C) \otimes C$ to $M_6(C)$ as a tensor product $A_1 \otimes A_2 \otimes x$

$$\begin{aligned} A_1 &= \begin{pmatrix} A & . & . \\ . & A & . \\ . & . & A \end{pmatrix} , \\ A_2 &= \begin{pmatrix} A & . \\ . & x \end{pmatrix} . \end{aligned} \tag{2.5.3}$$

Bratteli diagrams of infinite-dimensional von Neumann algebras are obtained as limiting cases of finite-dimensional ones (see **Fig. 2.1**).

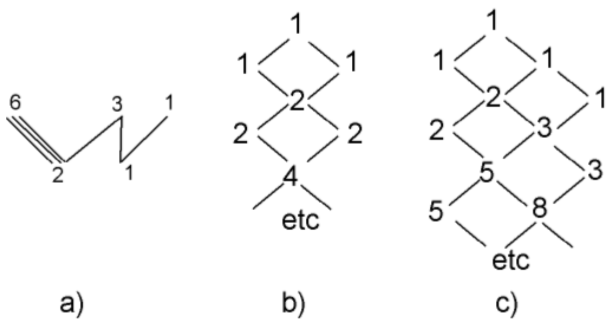

Figure 2.1: a) Illustration of Bratteli diagram. b) and c) give Bratteli diagrams for $n = 4$ and $n = 5$ Temperley Lieb algebras

2. Temperley Lieb algebras approximate II_1 factors

The hierarchy of inclusions of with $|M_{i+1} : M_i| = r$ defines a hierarchy of Temperley-Lieb algebras characterizable using Bratteli diagrams. The diagrams b) and c) of the figure **??** at the end of the chapter characterize the Bratteli diagrams for $n = 4$ and $n = 5$. For $n = 4$ the dimensions of algebras come in powers of 2 in accordance with the fact $r = 2$ is the dimension of the effective tensor factor of II_1.

For $n = 5$ and $B_m = \{1, e_1, ..., e_m\}$ the dimensions of the two tensor factors of the Temperley Lieb-representation are two subsequent Fibonacci numbers F_{m-1}, F_m ($F_{m+1} = F_m + F_{m-1}$, $F_1 = 1, F_2 = 1$) so that the dimension of the tensor product is $dim(B_m) = F_m F_{m-1}$. One has $dim(B_{m+1})/dim(B_m) = F_m/F_{m-2} \rightarrow \Phi^2 = 1 + \Phi$, the dimension of the effective tensor factor for the corresponding hierarchy of II_1 factors. Hence the two dimensional hierarchies "approximate" each other. In fact, this result holds completely generally.

The fact that r is approximated by an integer in braid representations is highly interesting from the point of view of TQC. For 3-braid representation the dimension of Temperley-Lieb representation is 2 for all values of n so that 3-braid representation defines single (topo)logical qubit as $(AA) - A - A$ realization indeed assumes. One could optimistically say that TGD based physics automatically realizes topological qubit in terms of 3-braid representation and the challenge is to understand the details of this realization.

2. Why Golden Mean should be favored?

The following argument suggests a physical reason for why just Golden Mean should be favored in the magnetic flux tube systems.

1. Arnold [B49] has shown that if Lorentz 3-force satisfies the condition $F_B = q(\nabla \times B) \times B = q\nabla\Phi$, then the field lines of the magnetic field lie on $\Phi = constant$ tori. On the other hand, the vanishing of the Lorentz 4-forces for solutions of field equations representing asymptotic self-organized states, which are the "survivors" selected by dissipation, equates magnetic force with the negative of the electric force expressible as qE, $E = -\nabla\Phi + \partial_t A$, which is gradient if the vector potential does not depend on time. Since the vector potential depends on three CP_2 coordinates only for $D = 3$, this seems to be the case.

2. The celebrated Kolmogorov-Arnold-Moser (KAM) theorem is about the stability of systems, whose orbits are on invariant tori characterized by the frequencies associated with the n independent harmonic oscillator like degrees of freedom. The theorem states that the tori for which the frequency ratios are rational are highly unstable against perturbations: this is due to resonance effects. The more "irrational" the frequencies are, the higher the stability of the orbits is, and the most stable situation corresponds to frequencies whose ratio is Golden Mean. In quantum context the frequencies for wave motion on torus would correspond to multiples $\omega_i = n2\pi/L_i$, L_i the circumference of torus. This poor man's argument would suggest that the ratio of the circumferences of the most stable magnetic tori should be given by Golden Mean in the most stable situation: perhaps one might talk about Golden Tori!

3. Golden Mean and microtubuli

What makes this observation so interesting is that Fibonacci numbers appear repeatedly in the geometry of living matter. For instance, micro-tubuli, which are speculated to be systems performing quantum computation, represent in their structure the hierarchy Fibonacci numbers $5, 8, 13$, which brings in mind the tensor product representation $5 \otimes 8$ of B_5 (5 braid strands!) and leads to ask whether this Temperley-Lieb representation could be somehow realized using microtubular geometry.

According to the arguments of [B23] the state of n anyons corresponds to 2^{n-1} topological degrees of freedom and code space corresponds to F_n-dimensional sub-space of this space. The two conformations of tubulin dimer define the standard candidate for qubit, and one could assume that the conformation correlates strongly with the underlying topological qubit. A sequence of 5 *resp.* 8 tubulin dimers would give 2^4 *resp.* 2^7-dimensional space with $F_5 = 5$- *resp.* $F_7 = 13$-dimensional code sub-space so that numbers come out nicely. The changes of tubulin dimer conformations would be induced by the braid groups B_4 and B_7. B_4 would be most naturally realized in terms of a unit of 5-dimers by regarding the 4 first tubulins as braided punctures and 5th tubulin as the passive puncture. B_7 would be realized in a similar manner using a unit of 8 tubulin dimers.

Flux tubes would connect the subsequent dimers along the helical 5-strand *resp.* 8-strand defined by the microtubule. Nearest neighbor swap for the flux tubes would induce the change of the tubulin conformation and induce also entanglement between neighboring conformations. A full 2π helical twist along microtubule would correspond to 13 basic steps and would define a natural TQC program module. In accordance with the interpretation of II_1 factor hierarchy, (magnetic or electric) flux tubes could be assumed to correspond to $r = 2$ II_1 factor and thus carry 2-dimensional representations of $n = 5$ or $n = 4$ 3-braid group. These qubits could be realized as topological qubits using $(AA) - A$ system.

Topological entanglement as space-time correlate of quantum entanglement

Quantum-classical correspondence encourages to think that bound state formation is represented at the space-time level as a formation of join along boundaries bonds connecting the boundaries of 3-space sheets. In particular, the formation of entangled bound states would correspond to a topological entanglement for the flux tubes forming braids. The light-likeness of the boundaries of the bonds gives a further support for this identification. During macro-temporal quantum coherence a sequence of quantum jumps binds effectively to single quantum jump and subjective time effectively ceases to run. The light-likeness for the boundaries of bonds means that geometric time stops and is thus natural space-time correlate for the subjective experience during macro-temporal quantum coherence.

Also the work with TQC lends support for a a deep connection between quantum entanglement and topological entanglement in the sense that the knot invariants constructed using entangling 2-gate R can detect linking. Temperley-Lieb representation for 3-braids however suggests that topological entanglement allows also single qubit representations for with quantum entanglement plays no role. One can however wonder whether the entanglement might enter into the picture in some natural manner in the quantum computation of Temperley-Lieb representation. The idea is simple: perhaps the physics of $(AA) - A - A$ system forces single qubit representation through the simple fact that the state space reduces in 4-batch to single qubit by topological constraints.

For TQC the logical qubits correspond to entangled states of anyon Cooper pair (AA) and second anyon A so that the quantum superposition of qubits corresponds to an entangled state in general. Several arguments suggest that logical qubits would provide Temperley-Lieb representation in a natural manner.

1. The number of braids inside 4-anyon batch (or 3-anyon batch in case that (AA) can decay temporarily during braid operation) 3 so that by the universality this system allows to compute the unitary Temperley-Lieb braid representation. The space of logical qubits equals to the entire state space since the number of qubits represented by topological ground state degeneracy is 1 instead of the expected three since $2n$ anyon system gives rise to 2^{n-1}-fold vacuum degeneracy. The degeneracy is same even when two of the anyons fuse to anyon Cooper pair. Thus it would seem that the 3-braid system in question automatically produces 1-qubit representation of 3-braid group.

2. The braiding matrices $\Phi(s_1)$ and $\Phi(s_2)$ are different and only $\Phi(s_2)$ mixes qubit values. This can be interpreted as the presence of two inherently different braid operations such that only the second braiding operation can generate entanglement of states serving as building blocks of logical qubits. The description of anyons as 2-dimensional wormholes led to precisely this picture. The braid group reduces to braid group for one half of anyons since anyon and its partner at the end of wormhole are head and feet of single dancer, and the anyon pair (AA) forming bound state can change partner during swap operation with anyon A and this generates quantum entanglement. The swap for anyons inside (AA) can generate only relative phase.

3. The vanishing of the topological charge in a pairwise manner is the symmetry which reduces the dimension of the representation space to 2^{n-1} as already found. For $n = 4$ only single topological qubit results. The conservation and vanishing of the net topological charge inside each batch gives a constraint, which is satisfied by the maximally entangling R-matrix R so that it could take care of braiding between different 4-batches and one would have different braid representation for 4-batches and braids consisting of them. Topological quantization justifies this picture physically. Only phase generating *physical* 1-gates are allowed since Hadamard gate would break the conservation of topological charge whereas for *logical* 1-gates entanglement generating 2-gates can generate mixing without the breaking of the conservation of topological charges.

Summary

It deserves to summarize the key elements of the proposed model for which the localization (in the precise sense defined in [B40]) made possible by topological field quantization and Z_4 valued topological charge are absolutely essential prerequisites.

1. $2n$-anyon system has 2^{n-1}-fold ground state degeneracy, which for $n = 2$ leaves only single logical qubit. In standard physics framework $(AA)-A-A$ is minimal option because the total homology charge of the system must vanish. In TGD $(AA)-A$ system is enough to represent 3-braid system if the braid operation between AA and A can be realized as an exchange of the dancing partner. This option makes sense because the anyons with opposite topological charges at the ends of wormhole threads can be negative energy anyons representing the final state of the braid operation. A pair of magnetic flux tubes is needed to realize single anyon-system containing braid.

2. Maximally entangling R-matrix realizes braid interactions between $(AA)-A$ systems realized as 3-braids inside larger braids and the space of logical qubits is equivalent with the space of realizable qubits. The topological charges are conserved separately for each $(AA)-A$ system. Also the more general realization based on n-braid representations of Temperley-Lieb algebra is formally possible but the different topological realization of braiding operations does not support this possibility.

3. Temperley-Lieb 3-braid representation for $(AA) - A - A$ system allows to realize also 1-gates as braid operations so that topology would allow to avoid the fine-tuning associated with 1-gates. Temperley-Lieb representation for $\phi = exp(i\pi/10)$ satisfies all basic constraints and provides representation of the modular functor expressible using $k = 3$ Witten-Chern-Simons action. Physically 1-gates are realizable using Φ_1 acting as phase gate for anyon pair inside (AA) and $\Phi(s_2)$ entangling (AA) and A by partner exchange. The existence of single qubit braid representations apparently conflicting with the identification of topological entanglement as a correlate of quantum entanglement has an explanation in terms of quantum computation under topological symmetries.

2.5.3 Zero Energy Topological Quantum Computations

As already described, TGD suggests a radical re-interpretation for matter antimatter asymmetry in long length scales. The asymmetry would be due to the fact that ground state for fermion system corresponds to infinite sea of negative energy fermions and positive energy anti-fermions so that fermions would have positive energies and anti-fermions negative energies.

The obvious implication is the possibility to interpret scattering between positive energy states as a creation of a zero energy state with outgoing particles represented as negative energy particles. The fact that the quantum states of 3-dimensional light-like boundaries of 3-surfaces represent evolutions of 2-dimensional quantum systems suggests a realization of topological quantum computations using physical boundary states consisting of positive energy anyons representing the initial state of anyon system and negative energy anyons representing the outcome of the braid operation.

The simplest scenario simply introduces negative energy charge conjugate of the $(AA) - A$ system so that no deviations from the proposed scenario are needed. Both calculation and its conjugate are performed. This picture is the only possible one if one assumes that given space-time sheet contains either positive or negative energy particles but not both and very natural if one assumes ordinary fermionic vacuum. The quantum computing system would could be generated without any energy costs and even intentionally by first generating the p-adic space-time sheets responsible for the magnetic flux tubes and anyons and then transformed to their real counterparts in quantum jump. This double degeneracy is analogous to that associated with DNA double strand and could be used for error correction purposes: if the calculation has been run correctly both anyon Cooper pairs and their charge conjugates should decay with the same probability.

Negative energies could have much deeper role in TQC. This option emerges naturally in the wormhole handle realization of TQC. The TGD realization of 1-gates in 3-braid Temperley-Lieb representation uses anyons of opposite topological charges at the opposite ends of threads connecting magnetic flux tube boundaries. Single 3-braid unit would correspond to positive energy electronic anyons at the first flux tube boundary and negative energy positronic anyons at the second flux tube boundary. The sequences of 1-gates represented as 3-braid operations would be coded by a sequence of 3-braids representing generators of 3-braid group along a pair of magnetic flux tubes. Of course, also n-braid operations could be coded in the similar manner in series. Hence TQC could be realized using only two magnetic flux tubes with n-braids connecting their boundaries in series.

Condensed matter physicist would probably argue that all this could be achieved by using electrons in strand and holes in the conjugate strand instead of negative energy positrons: this would require only established physics. One can however ask whether negative energy positrons could appear routinely in condensed matter physics. For instance, holes might in some circumstances be generated by a creation of an almost zero energy pair such that positron annihilates with a fermion below the Fermi surface. The signature for this would be a photon pair consisting of ordinary and phase conjugate photons.

The proposed interpretation of the S-matrix in the Universe having vanishing net quantum numbers encourages to think that the S-matrices of 2+1-dimensional field theories based on Witten-Chern-Simons action defined in the space of zero (net) energy states could define physical states for quantum TGD. Thus the 2+1-dimensional S-matrix could define quantum states of 4-dimensional theory having interpretation as states representing "self-reflective" level representing in itself the S-matrix of a lower-dimensional theory. The identification of the quantum state as S-matrix indeed makes sense for light-like surfaces which can be regarded as limiting cases of space-like 3-surfaces defining physical state and time-like surfaces defining a time evolution of the state of 2-dimensional system.

Time evolution would define also an evolution in topological degrees of freedom characterizing ground states. Quantum states associated with light-like (with respect to the induced metric of space-time sheet) 3-dimensional boundaries of say magnetic flux tubes would define quantum computations as modular functors. This conforms with quantum-classical correspondence since braids, the classical states, indeed define quantum computations.

The important implication would be that a configuration which looks static would code for the dynamic braiding. One could understand the quantum computation in this framework as signals propagating through the strands and being affected by the gate. Even at the limit when the signal propagates with light velocity along boundary of braid the situation looks static from outside. Time evolution as a state could be characterized as sequence of many-anyon states such that basic braid operations are realized as zero energy states with initial state realized using positive energy anyons and final state realized using negative energy energy anyons differing by the appropriate gate operation from the positive energy state.

In the case of n-braid system the state representing the S-matrix $S = S^1S^2....S^n$ associated with a concatenation of n elementary braid operations would look like

$$\begin{aligned} |S\rangle &= P_{k_1}S^1_{k_1k_2}P_{k_2}S^2_{k_2k_3}P_{k_3}S^3_{k_3k_4}\cdots \ , \\ P_k &= |k,<\rangle|k,>\rangle \ . \end{aligned} \tag{2.5.4}$$

Here S^k are S-matrices associated with gates representing simple braiding operations s_k for $n+1$ threads connecting the magnetic flux tubes. P_k represents a trivial transition $|k\rangle \rightarrow |k \rightarrow k\rangle$ as zero energy state $|k,>0\rangle|k,<\rangle$. The states P_k represent matrix elements of the identification map from positive energy Hilbert space to its negative energy dual.

What would happen can be visualized in two alternative ways.

1. For this option the braid maps occur always from flux tube 1 to flux tube 2. A braiding transition from 1 to 2 is represented by S^{k_1}; a trivial transition from 2 to 1 is represented by P_k; a braiding transition from 1 to 2 is represented by S^{k_2}, etc... In this case flux tube 1 contains positive energy anyons and flux tube 2 the negative energy anyons.

2. An alternative representation is the one in which P_k represents transition along the strand so that S^k *resp.* S^{k+1} corresponds to braiding transition from strand 1 to 2 *resp.* 2 to 1. In this case both flux tubes contain both positive and negative energy anyons.

2.6 Quantum computations without definite causal structure: TGD view

I encountered a link to a interesting popular article *"Causal Witness" Provides First Experimental Evidence Of Indefinite Causal Order* (see `http://tinyurl.com/lwaurk3`). The article tells about an article *Experimental verification of an indefinite causal order* by Rubio *et al* [B26](see `http://tinyurl.com/ltamjbv`). In the following are my first impressions.

In TGD Zero Energy Ontology (ZEO) replaces ordinary ontology and the arrow of time is not fixed, and it is interesting to see whether superposition of different causal orders related by time inversion T for causal diamond (CD) and SWITCH could be realized in ZEO. The twistor lift of TGD leads to the proposal that CD is accompanied by a Minkowskian generalization of self-dual Kähler form $J(CD)$. Although the moduli space of CDs allows to avoid breaking of Poincare invariance, self-duality of $J(CD)$ leads to violation of T implying that different causal orders correspond to disjoint sectors of "world of classical worlds". This makes possible also superposition of different causal orders and SWITCH would map these sectors to each other.

2.6.1 Indefinite causal order

The abstract of the article Rubio *et al* might give some idea about what is involved.

Investigating the role of causal order in quantum mechanics has recently revealed that the causal relations of events may not be a priori well-defined in quantum theory. Although this has triggered a growing interest on the theoretical side, creating processes without a causal order is an experimental task. We report the first decisive demonstration of a process with an indefinite causal order. To do this, we quantify how incompatible our setup is with a definite causal order by measuring a "causal witness". This mathematical object incorporates a series of measurements that are designed to yield a certain outcome only if the process under examination is not consistent with any well-defined causal order. In our experiment, we perform a measurement in a superposition of causal orders—without destroying the coherence—to acquire information both inside and outside of a causally non-ordered process. Using this information, we experimentally determine a causal witness, demonstrating by almost 7 SDs that the experimentally implemented process does not have a definite causal order.

Unfortunately, I do not have prerequisites to say anything interesting about the delicacies of the experiment itself. Since causal order is fixed by that associated with space-time in standard physics, the implications of the experiment could be world view changing. The key quantum information theoretic notions are causal order, causal separability, quantum wittness, quantum process called SWITCH changing causal order, and superposition of causal orders.

1. The notion of causal order is discussed in the article "Quantum correlations with no causal order" by Oreshkov *et al* [B42] (see `http://tinyurl.com/l7wb5zh`). One has two events A and B. If they are causally separable, one can tell which causes which. In Minkowski space causally separable events would connected by a time-like curve. If not, one cannot speak about causal order. One can tell whether A precedes B or vice versa. For light-like distances, the situation is not so clear.

   Relaxing the standard assumption about fixed arrow of time one can at quantum level consider also a situation in which one has quantum superposition of different causal orders. One has causal non-separability.

2. The notion of causal wittness [B18] (see `http://tinyurl.com/jwzo3lq`) provides a method allowing to deduce experimentally whether the process is causally separable or not. The notion is similar to that of entanglement wittness (see `http://tinyurl.com/mwjb7um`) allowing to deduce whether the two systems are entangled. Essentially one has observable whose expectation is negative for states with indefinite causal order and positive for those with definite causal order. Causal wittness is not universal but must be constructed for each causally indefinite state separately. The construction of causal wittness expectation value of operator is far from trivial and requires deeper understanding of operator theory. The abstract definition goes as follows:

Causal wittness represents a set of quantum operations, such as unitaries, channels, state preparations, and measurements, whose expectation value is non-negative as long as all the operations are performed in a definite causal order, i.e., as long as only causally separable resources are used. The observation of a negative expectation value is thus sufficient to conclude that the operations were not performed in a definite order.

Causal witness can be constructed efficiently and the construction is discussed in [B19] (see `http://tinyurl.com/lxer962`).

3. SWITCH is a further basic notion. One has two events A and B, which can be connected by a time-like curve. One can tell whether A precedes B or vice versa. SWITCH is a quantum operation switching the causal order. The obvious manner to do this would permute A and B and would require "time travel" not allowed in standard physics. Obviously, SWITCH cannot be realized as operation respecting fixed causal order.

4. If superpositions of causal orders are possible, one can have a situation in which causal order is indefinite. Also this is something which does not conform the ordinary view about physics in fixed space-time but is allowed by postulates for quantum computation and SWITCH represents an example of quantum computation impossible with a fixed causal order.

Needless to say, the notions of causal order and superposition of causal orders are revolutionary ideas and the article claims that they have been experimentally verified. Standard physics framework does not allow SWITCH. Therefore there are excellent motivations to find whether these notions and the operation of SWITCH could be understood in TGD framework.

In TGD Zero Energy Ontology (ZEO) replaces ordinary ontology and the arrow of time is not fixed, and it is interesting to see whether superposition of different causal orders related by time inversion T for causal diamond (CD) and SWITCH could be realized in ZEO. The twistor lift of TGD leads to the proposal that CD is accompanied by a Minkowskian generalization of self-dual Kähler form $J(CD)$ [K13, L37]. Although the moduli space of CDs allows to avoid breaking of Poincare invariance, self-duality of $J(CD)$ leads to violation of T implying that different causal orders correspond to disjoint sectors of "world of classical worlds". This makes possible also superposition of different causal orders and SWITCH would map these sectors to each other.

2.6.2 ZEO and discrete symmetries for twistor lift of TGD

Some background about TGD is necessary in order to proceed.

1. Zero Energy Ontology (ZEO) is the cornerstone of TGD and TGD inspired theory of consciousness. Zero energy states appear as two variants and correspond to different WCW spinor fields (WCW for "world of classical worlds"). I have proposed that they correspond also to WCW spinor fields localized to different sectors of WCW but this might be unnecessarily strong assumption.

   Zero energy states for given basis have been subject to a state function reduction at either boundary of CD - passive boundary. Neither the passive boundary nor the members of state pairs at it appearing in the superposition of state pairs are affected in repeated state function reductions. One has what I have called generalized Zeno effect identified as conscious entity - self.

   At the opposite boundary the states evolve: every state function reduction at active boundary is preceded by a unitary time evolution ending to a localization of the active boundary of CD, which can be also seen as a state function reduction [L38]. The temporal distance between the tips of CD increases in this process and gives rise to clock time and experienced flow of time.

   Eventually the first reduction to the opposite boundary occurs and the roles of active and passive boundary of CD are changed. One can say that time reversed zero energy state is obtained and begins to evolve. The first reduction to the opposite boundary would mean death of the conscious entity defined by the sequence of state function reductions at the same boundary and generation of time reversed re-incarnation of self.

2. Violation of T - to be discussed below - would also imply asymmetry between selves and their time reversals. For instance, the average duration for the state reduction sequences keeping boundary fixed could be different and second causal order could dominate giving rise to a dominating arrow of time. Since these reduction sequences are identified as correlates for conscious selves, the time reversed re-incarnations would live much shorter time. Biological systems might be an exception: in TGD inspired theory of consciousness sensory perception and motor action are time reversals of each other.

3. Fermionic oscillator operators associated with induced spinor fields allow to represent WCW gamma matrices as their linear combinations: Fermi statistics is geometrized. Fermionic oscillator operators define also quantum Boolean algebra in the sense that fermion numbers 1/0 correspond to the two Boolean values. One could say that quantum logic is square root of WCW Kähler geometry. This allows to interpretation the S-matrix for fermions as quantum Boolean map between quatum Boolean algebras at opposite boundaries. This is obviously important when one talks about quantum computation.

   In the approach to twistor amplitudes [K41, L37] fermions are localized at the boundaries of string world sheets defining light-like curves at the 3-D light-like orbits of partonic 2-surfaces, at which the signature of the induced metric changes from Minkowskian to Euclidian and has a vanishing determinant so that tangent space is effectively 3-D. The interpretation is in terms of strong form of holography (SH) stating that the data determining both space-time surface as preferred extremal and modes of the induced spinor field in the interior of space-time surface. SH predicts that both the bosonic and fermionic 4-D actions reduce to 2-D effective actions for string world sheets.

   The implication is that fermion states at the boundaries of CD are localized at discrete points of partonic 2-surfaces. One has of course amplitude over different locations of fermions at partonic 2-surfaces. The presence of fermionic string world sheets correlates the fermions at different partonic 2-surfaces and serves as correlate for entanglement in fermionic degrees of freedom.

4. The twistor lift of TGD [K41, K13, L37] has led to a rather detailed understanding of discrete symmetries CP, P,T. If M^4 factor of embedding space - or more precisely CD - is endowed with a generalized *self-dual* Kähler form $J(M^4)$ (analogs of magnetic and electric fields of same magnitude and direction), new violations of CP, P and T occurring in long scales and having no counterpart in standard model emerge. The reason is that CP, P and T do not respect the self-duality of M^4 Kähler form. The violations of Poincare invariance are avoided if one assumes moduli space for CDs containing the Lorentz boosts and translations of CD.

   The first guess is that T leaving the center point of CD invariant applied to the CD maps the 3-surfaces at the boundaries of CD to each other. The violation of T however implies that the image of the pair need not allow preferred extremal (space-time surface) connecting its members.

   One can however define the temporal mirror image of pair by mapping only the 3-surface at the passive boundary to the opposite boundary: preferred extremal property would determine the 3-surface at the passive boundary. This could imply that the sub-WCWs formed by pairs and the time reversals are disjoint and form different sectors of WCW as indeed assumed in [L38]. This realization of T allows also the possibility that the dynamics of preferred extremals is not strictly deterministic (true at least for p-adic space-time sheets).

   In absence of T violation T operation would also permute the values fermionic states partonic 2-surfaces at the boundaries of CD but if T is violated, can map only the state at the passive boundary to the opposite boundary and determine the state at original boundary from the hermitian conjugate of S-matrix in opposite time direction. The fermionic state at the opposite boundary would be superposition of states having only same total quantum numbers as the state at the passive boundary. The quantum numbers of individual fermions would not be sharp for non-trivial S-matrix if the zero energy states and their T images correspond to same sector of WCW.

   If T is not violated, zero energy states and their T-images would not correspond to the same sector of WCW. Obviously they would correspond to opposite causal orders, see below) This would force to give up the assumption that states at passive boundary are state function reduced. If T is violated globally, the zero energy states and their T-reversals would correspond to disjoint sectors of WCW, and the sectors would only correspond to different arrows of time. This option gives hopes about WCW localization the outcome of the measurement of causal order.

The union of sub-WCWs with opposite arrow of time is a space with fixed causal order plus additional binary digit characterizing the causal order. The state function for this binary digit could fix the causal order and quantum computation generating superposition of causal orders should generate entanglement with this bit.

5. What about the situation for a union of CDs? Different CDs should be able to have their own arrow of time. For instance, there are reasons to think that in living matter one can have subsystems with non-standard arrow of time [J20]. Also phase conjugate laser ray could be also example of this. This requires that WCW spinor fields associated with a union of CDs form a tensor product. Causal order need not be same for all CDs but characterizes the sub-WCW associated with CD forming a Cartesian factor of WCW so that WCW spinors for the CDs form tensor product.

2.6.3 Two views about SWITCH and superposition of causal orders

One can imagine two approaches to the identification of SWITCH operation and superposition of causal orders.

Option I: Unitary SWITCH as time reversal

The first option corresponds to corresponds to unitary "time travel" option.

1. As already proposed, SWITCH as a unitary operation could correspond to T. Time reversal operation T applied to the 3-surfaces at the boundaries of CD would naturally change the causal order for the zero energy state. If T is violated the state and its T-image belong to separate sectors of WCW. One could also have a superposition of zero energy states related by T and having different causal orders and localizable to the two sectors of WCW.

2. Is it possible to perform SWITCH as a unitary (as a matter fact, antiunitary) operation? If T maps the disjoint sectors to each other and maps fermionic time evolutions to their time reversals, SWITCH maps the two sectors of WCW to each other.

   Can one realize SWITCH mathematically as a unitary operation between fermionic state spaces. This seems possible: the tensor product of $S \otimes S^\dagger$ on tensor product of fermionic Fock spaces would realize this map. Whether SWITCH can be realized physically is of course another question.

Option II: Non-unitary SWITCH as the first state function reduction to the opposite boundary of CD

Could non-unitary SWITCH be realized as the first state function reduction to the opposite boundary - death of self followed by a re-incarnation as time-reversed self? In this case SWITCH is neither unitary nor deterministic. This SWITCH corresponds to non-unitary "time travel" option in the sense that self identified as passive boundary makes a time travel to the opposite boundary of CD by re-incarnating in non-deterministic manner.

What about the superposition of self and time reversed self as a superposition of causal orders? Schrödinger cat would be more than a catchy metaphor: it would indeed be a superposition of cat and re-incarnated cat! Should one take this seriously?

If the CDs with different arrow of time correspond to different sectors of WCW, different causal orders correspond to states localized in these sectors. A superposition of causal orders would correspond to WCW spinor field having component in both these sectors. If the state function reduction to opposite boundary of CD takes place at the level of entire WCW - or more realistically, for a Cartesian factor of WCW, it must be accompanied by a localization to either sector of WCW in order to avoid paradoxes.

I have already earlier work with TGD inspired ideas related to quantum computation. For more than decade ago I developed rather speculative model topological quantum computation in TGD framework [K3, K105]. One speculation about super-effective quantum computations is inspired by the analogy of selves with quantum computations halting, when the self dies and re-incarnates as time reversed self with clock time running in opposite direction at opposite boundary of CD [K9]. This would mean using the non-unitary SWITCH realized as state function reduction in quantum computation.

This allows to imagine a series of quantum computations at opposite boundaries proceeding as a sequence of re-incarnations so that the size of CD and thus clock time would grow in opposite directions during subsequent incarnations [L19]. Although the re-incarnation as time reversed self could have long life-time, it would not be seen by an observer near the former re-incarnation and the re-re-incarnation would appear at clock-time, which need not be much later than the time of previous death. One could imagine that the time-reversed selves could have very long life-time or that the self could die and re-incarnate very many times without any-one noticing it! The large amount of time spent in time reversed mode could explain the miraculous cognitive feats of mathematicians like Ramajunan and also the magic computational abilities of idiot savants able to factorize large integers without any idea about the notion of prime.

2.6.4 Higher level quantum computations and ZEO

From the article of Rubio *et al* one ends up to an article *Quantum computations without definite causal structure* by Chiribella *et al* (see `http://tinyurl.com/lgjkzhx`). The article considers a rather far reaching generalization of quantum computation. Ordinary quantum computation is a time evolution of quantum states followed by a state function reduction. Since the outcome of state function reduction halting the quantum computer program is non-deterministic, the extraction of the result involves statistical averaging over a large enough number of quantum computations to get the outcome, say prime factorization or a period of periodic function.

The notion of classical computation is generalized by Church. The computation need not be a function but can assign function to a function. One can continue this abstraction hierarchy indefinitely and it is realized formally in terms of so called Λ calculus (see `http://tinyurl.com/829fea8`). Could this hierarchy be extended to quantum computations? The quantum computation in question would be kind of super-computation assigning to quantum computation a quantum computation and entire hierarchy of quantum computations.

In TGD this kind of hierarchies emerge naturally. At space-time level there is hierarchy of space-time sheets: space-time sheet is (topologically) condensed to a larger space-time sheet and contains smaller space-time sheets condensed at it. The hierarchy of infinite primes corresponds to an infinite hierarchy of second quantizations and could relate to this hierarchy [K92] (see `http://tinyurl.com/m3tuo9q`. In each scale space-time sheets would be particles consisting of smaller particles consisting of ... Even galaxy could be seen as elementary particle in some scale characterizing the galactic space-time sheet.

The analog of quantum computational hierarchy emerges quite concretely in ZEO. The simplest zero energy states have positive and negative energy states with opposite total quantum numbers at the opposite boundaries of CD (intersection of future and past directed light-cones). One can have CDs within CDs. Furthermore, the positive/negative energy states assignable to the boundaries of CD could be also zero energy states associated with smaller CDs near the boundaries of CD. The simplest zero energy states correspond to quantum evolution representing ordinary quantum computation. Higher level zero energy stats would represent time evolution assigning to a quantum computation represented as zero energy state at the boundary of CD a second quantum computation at opposite boundary of CD.

The fermionic representation of quantum Boolean algebra makes this hierarchy quite concrete. At lowest level unitary evolution connects positive and negative energy fermionic states at opposite boundaries of CD and unitary S-matrix characterizes the computation. Higher level computations connect zero energy states assignable to sub-CDs near the boundaries of CD.

2.6.5 Is conscious experience without definite causal order possible?

The exciting question is what the superposition of causal orders could mean from the point of view of conscious experience. What seems obvious is that in the superposition of selves with opposite arrows of clock-time there should be no experience about the flow of time in definite direction. Dissipation is associated with the thermodynamical arrow of time. Therefore also the sensory experience about dissipation expected to have unpleasant emotional color should be absent. This brings in mind the reports of meditators about experiences of timelessness. These states are also characterized by words like "bliss" and "enlightenment".

Why I find this aspects so interesting is due to my personal experience for about 32 years ago. I of course know that this kind of personal reminiscences in an article intended to be scientific, is like writing one's own academic death sentence. But I also know I long ago done this so that I have nothing to lose! The priests of the materialistic church will never bother to take seriously anything that I have written so that it does not really matter! This experience - I dared to talk about enlightenment experience - changed my personal life profoundly, and led to the decision to continue work with TGD instead of doing full-day job to make money and keeping TGD as a kind of hobby. The experience also forced to realize that our normal conscious experience is only a dim shadow of what it can be and stimulated the passion to understand consciousness.

In this experience my body went to a kind of light flowing state: liquid is what comes in mind. All unpleasant sensations in body characterizing the everyday life (at least mine!) suddenly disappeared as this phase transition propagated through my body. As a physicist I characterized this as absence of dissipation, and I talked to myself about a state of whole-body consciousness.

There was also the experience about moving in space in cosmic scales and the experience about the presence of realities very different the familiar one. Somehow I saw these different worlds from above, in bird's eye of view. I also experienced what I would call time travel and re-incarnation in some other world.

Decades later I would ask whether my sensory consciousness could have been replaced with that only about my magnetic body only. In the beginning of the experience there was indeed a concrete feeling that my body size had increased with some factor. I even had the feeling the factor was about 137 (inverse of the fine structure constant) but this interpretation was probably forced by my attempt to associate the experience with something familiar to physicist! Although I did all the time my best to understand what I was experiencing, I did not direct my attention to my time experience, and cannot say whether I experienced the presence or absence of time or time flow.

Towards the end of the experience I was clinically unconscious for about day or so. I was however conscious. For instance, I experienced quite concretely how the arrow of time flow started to fluctuate forth and back. I somehow knew that permanent change would mean death and I was fighting to preserve the usual arrow of time. My childhood friend, who certainly did not know much about physics, told about about alternation of the arrow of time during a state that was classified by psychiatrists as an acute psychosis.

2.7 Retrocausality and TGD

The comments below were inspired by a popular article "Physicists provide support for retrocausal quantum theory, in which the future influences the past" in Phys.org (see `http://tinyurl.com/yd4rwsg7`) telling about the preprint "Is a time symmetric interpretation of quantum theory possible without retrocausality?" of Leifer and Pusey related to the notion of retrocausality [B41] (see `http://tinyurl.com/yd59jvd5`). Retrocausality means the possibility of causal influences propagating in non-standard time direction. Retrocausality has been also proposed by Cramer as a possible manner to obtain deterministic quantum mechanics and allowing to interpret wave functions as real objects. Bell theorem and Kochen-Specker theorem however pose difficult challenges for this program and the condition that the theory is classical in strong sense (all observables have well-defined values) seems impossible.

The work is interesting from TGD view point for several reasons.

1. TGD leads to a new view about reality solving the basic problem of quantum measurement theory. In ZEO quantum states are replaced by zero energy states which are analogous to pairs of initial and final states in ordinary ontology and can be regarded as superpositions

of classical deterministic time evolutions. The sequence of state function reductions means sequence of re-creations of the superpositions of classical realities. The TGD based view about scattering amplitudes has a rather concrete connection with the view of Cramer as I interpret it. There is however no attempt to reduce quantum theory to a purely classical theory. The notion of "world of classical worlds" consisting of classical realities identified as space-time surfaces replaces space-time as a fixed observer independent reality in TGD.

2. Retrocausality is basic aspect of TGD. Zero Energy Ontology (ZEO) predicts that both arrows of time are possible. In this sense TGD is time symmetric. On the other hand, the twistor lift of TGD predicts a violation of time reflection T and this might imply that second arrow of causality dominates in some sense. The ZEO based view about state function reduction essential for TGD inspired theory of consciousness and implying generalized Zeno effect giving rise to conscious entities -"selves" - is also essential. One might say that when conscious entity dies it re-incarnates as time-reversed self.

3. The possibility of superposing states with opposite causal arrows [B26] (see `http://tinyurl.com/ltamjbv`) is a fascinating idea and its plausibility is discussed already earlier in TGD framework [L36] (see `http://tinyurl.com/y9tgfxbf`).

In the sequel I will discuss the articles from TGD point of view criticizing the hidden assumptions about the nature of time leading to the well-known problems of quantum measurement theory and consider also the concrete implications for theories of consciousness. Also the empirical evidence for retrocausality is discussed briefly. Contrary to the article the discussion is non-technical: I do not believe that the introduction of technicalities helps to understand the deep conceptual problems involved and possible solutions to them.

2.7.1 Retrocausality

In this section I will explain my own view about retrocausality but will not introduce the TGD view yet.

Retrocausality: with or without real quantum states

Leifer and Pusey use as a starting point the work of Hue Price [B33] (see `http://tinyurl.com/yaa8wogr`), which claims that if quantum states are real and quantum world is time-symmetric then theory must allow retrocausal influences.

What does one mean when one says that quantum states are real? In standard ontology (PEO) this is usually taken to mean that physics is deterministic and universe corresponds to single solution of field equations. This leads of course to conflict with the facts behind quantum measurement theory. State function reductions are not deterministic. This has led to various interpretations such as Copenhagen interpretation giving up ontology altogether and assuming only epistemology: wave function describes only our knowledge about something, which does not exist. One has paradox.

Retrocausality has been proposed to save the notion of reality as something unique and deterministic. A stronger condition is that all observables have sharp values as in classical mechanics. For Schrödinger amplitudes - which can be seen also as purely classical objects - the observables are defined by expectation values of operators and simultaneous eigenstates of non-commuting observables are not possible and classicality in strong sense fails.

Cramer's transcactional interpretation of quantum theory (see `http://tinyurl.com/zpupb8g`) indeed assumes that both causal arrows are possible.

1. To my best understanding this would mean that there are two time evolutions: the usual one from past to future and the retrocausal one from future to past. At some 3-dimensional hyper-surface of space-time these time evolutions would meet each other and be glued together. At this hyper-surface there would be discontinuities. This picture might lead to the standard statistical predictions of quantum measurement theory such as reduction probabilities if the two states would correspond to eigenstates of corresponding measured observables and transition amplitudes are given by Born rule. Note that Cramer's theory is completely deterministic and there is no room for free will.

2. Realism should be consistent with the experimentally verified Bell theorem supporting non-locality of quantum theory made possible by quantum entanglement. The hope is that retrocausality is consistent with Bell theorem predicting correlations between distant measurements not possible to understand in terms of classical probabilities. The key point is the interference of amplitudes which in quantum theory replaces summation of probabilities.

3. There is also Kochen-Specker theorem (see `http://tinyurl.com/q4vb9j5`) stating that it is not possible to have classical description of all quantum observables when their algebra is non-commutative. If realism is taken to mean that all observables have well-defined values then there is no hidden variable theory allowing realism. Even retrocausality can help only if realism is formulated in less demanding manner.

Leifer and Pusey give up the debatable assumption about reality of quantum states and claim of having proved the same result. The article is rather technical and I have not checked the details. Intuitively the result of course looks rather obvious. Of course, it is possible that theory is not fully time-symmetric and there are still retrocausal influences. For instance, the violation of time reflection symmetry and this could make the ordinary causal influences longer lasting than the retrocausal ones.

Cannot have both time symmetry and no-retrocausality

Leifer and Pusey show that time symmetry and non-allowance of retrocausality leads to a contradiction but they do not assume the reality of quantum states in the sense of PEO. Time symmetry implies that forward and backward processes have same probabilities. Impossibility of retrocausality obviously requires that the probabilities for retrocausal processes vanish.

Intuitively it is clear that time symmetry is more or less equivalent with the possibility of retrocausality meaning possibility of signals propagating in non-standard time direction. There are however many poorly understood issues.

1. What does one mean with signal? How can one conclude that the time evolution of say electromagnetic field corresponds to signal (or influence) in a given time direction? One possibility is that positive frequency photons correspond to signals to future. In quantum field theories (QFTs) positive energy photons correspond to creation operators and negative energy photons to annihilation operators. By $E = hf$ and its generalization positive frequencies correspond to positive energies. This would code for the selection of arrow of time and causality. This selection has nothing to do with thermodynamics and second law. One could call this ontology positive energy ontology (PEO).

2. It is far from obvious whether the time of physicist geometrized by Einstein can be identified with the experienced time is correct. This identification is done also in the work of Leifer and Pusey. The arrow of time is naturally assignable to subjective time but not to geometric time. Certainly these two times correlate strongly. We can experience subjective time directly but also use physical processes such as oscillators serving as clocks measuring geometric time, and this gives correspondence between the sequence of mental images and the position of the pointer of the clock.

   This strong correlation does not justify the identification of the two times. For instance, subjective time seems to have no future, only the moment "Now" is experienced directly, and there are only memories (even sensory ones) about the past. Geometric time has no preferred value and seems to correspond to eternity. There are therefore dramatic differences between the two times but for some reason they are usually identified.

3. Thermodynamics and second law are certainly closely related to subjective time. Thermodynamical predictions in turn rely kinetic theory with various reaction rates deduced from quantum theory. Non-determinism of state function reduction is what gives to the second law basically. Entropy increases due to state function reduction in the direction of time, which corresponds to a direction in which energies (frequencies for photons) are positive. If subjective time and geometric time are not identified this assumption becomes questionable and one can wonder whether the causal arrow is property of Universe or of quantum state only.

For instance, could thermodynamical arrow correspond to non-standard arrow of geometric time?

What time symmetry would mean if one does not identify subjective and geometric time? Is there symmetry with respect to subjective or geometric time or both? Could the causal arrow be a property of quantum state? Is it possible to have both causal arrows without conflict with second law or should one generalize second law so that it applies in reverse direction of geometric time for systems allowing retrocausality?

2.7.2 The notions of reality and retrocausality in TGD context

Consider next what one can say about the notion reality and retrocausality in TGD framework.

About the notion of reality in TGD framework

In TGD framework the question about the relationship between geometric and experienced time leads to a new view about state function reduction solving the basic paradox of standard quantum measurement theory and forces to replace the notion of classical reality with quantum superposition of realities. The new notions are "world of classical worlds" (WCW) and zero energy ontology (ZEO).

1. The key question is whether subjective and geometric time are identical. Could it be that these times are not same? If so, one would have two causalities: causality of state function reductions and causality of field equations. Could state function reductions occur between entire deterministic time evolutions rather than tinkering with single time evolution making it non-deterministic?

   This would force to give up the idea about single 4-D reality and replace it with a space of realities. In quantum theory one would be forced to speak of quantum superposition of these classical realities. Each state function reduction would re-create the superposition of 4-D classical realities identified as deterministic time evolutions. One would have realism in more general sense: quantum states would be quantum superpositions of classical realities giving rise to the "world of classical worlds" (WCW). Quantum jumps would allow continual re-creation of classical realities making possible evolution.

2. What does one mean with WCW? The notion of WCW from the view about TGD as a generalization of quantum field theory and string models. One replaces point-like particles with 3-D surfaces, whose 4-D orbits have interpretation as space-time surfaces. This of course means a considerable generalization of the notion of space-time. Particles can be seen as smaller space-times glued to larger space-times looking like particles in a rougher resolution.

   Given sector of WCW correspond to the space of space-time surfaces (generalizing particle world lines) inside 8-D causal diamond (CD), which is diamond like intersection of future and past directed light-cones with points replaced with CP_2. By holography these space-time surfaces are determined by 3-D surfaces at opposite boundaries of CD. To be precise, instead of ordinary holography one has strong form of holography (SH) meaning that 2-D data determine the classical dynamics and also quantum dynamics to high extent.

   This view is obviously something new. Classically physical states are not characterized by the initial values - of say coordinates and velocities at *time=constant* snapshot - but by their boundary values at the future and past boundaries of CD. Initial value problem has changed to boundary value problem. One gives initial and final values but only for coordinates, one might say. One has ZEO rather than PEO. This is essential from the point of view of retrocausality.

3. By its infinite-dimensionality WCW Kähler geometry is essentially unique and even the choice of the embedding space as $H = M^4 \times CP_2$ is unique by twistorial considerations [L37]. One might say WCW as the space of classical realities is the unique reality, maybe one should call it **THE REALITY**.

4. The wave functions in WCW correspond to WCW spinor fields. WCW spinors correspond to many-fermion states at given space-time surface and spinor fields are these spinors extended to spinor fields in WCW. All fundamental particles reduce to many-fermion states. This picture is a completely straightforward generalization of the notion of wave function in Minkowski space obtained by replacing point like particles with 3-surfaces. "Center of mass" degrees of freedom for 3-surfaces indeed are indeed characterized by $M^4 \times CP_2$-coordinates.

   These WCW spinor fields can be said to be purely classical spinor fields. There is no second quantization at WCW level. Therefore the only genuinely quantal aspect of quantum TGD would be state function reduction, which makes possible conscious entities with free will and leads to the notion of subjective time besides geometric time.

5. Quantum classical correspondence (QCC) is one of the basic principles of TGD and says that classical physics is exact part of quantum physics. The space-time surfaces in the quantum superposition are preferred extremals of certain action principle. "Preferred" means that SH holds true. In standard path integral approach one would have path integral over all possible space-time surfaces, now only over the preferred extremals. For integrable theories about which TGD seems to be an example, these two views are more or less equivalent. QCC states that the classical Cartan algebra Noether charges for preferred extremals in superposition are identical with eigenvalues of corresponding quantal charges. One could consider even the possibility that all classical Noether charges for the preferred extremals in the superposition are same as the expectation values of their quantum counterparts.

6. Cramer's view about state function reduction as gluing together of causal and retrocausal solutions of field equations together at 3-D surface has a highly interesting analogy in TGD. Elementary particle vertices correspond to this kind of gluing of corresponding space-time surfaces together along their ends [K41, L37]. At partonic level one has analogy of three-particle Feynman vertex. The three external lines of vertex correspond to three 3-D lightlike orbits of partonic 2-surfaces defining boundaries between space-time regions with Minkowskian and Euclidian signature of the induced metric. The vertex corresponds to partonic 2-surface at which these orbits are glued together along their ends. There is also gluing of space-time surfaces along their 3-D ends which could be located to boundaries of a sub-CD within larger CD containing initial and final states of particle reaction at its boundaries. The amplitudes at vertices are obtained using the QFT analog of Born rule.

   QCC would require that each space-time surface in the superposition of space-time surfaces in CD satisfies the Cramer type rules for each vertex involving sub-CD. The superposition of space-time surfaces would be superposition of potential state function reductions! The real state function reduction would pick up of them!

To sum up, in TGD there is no attempt to get rid of the non-determinism of state function reduction or force the reality to be classical in the sense of classical mechanics (local realism with well-defined values for all observables). Classical Noether charges are well-defined for all space-time surfaces but it is impossible to localize WCW spinor field to single space-time surface. This is already impossible by the fact that there is always finite measurement resolution: this notion indeed plays key role in TGD framework and involves p-adic length scale hierarchies and hierarchy of Planck constants labelling dark matter as phases of ordinary matter. Cramer's rule however resembles very strongly the TGD view about classical space-time correlates of particle reactions.

To my view the most precious gift of quantum theory based on ZEO is the possibility to understand free will without conflict with the determinism of basic field equations and various various trying to force old-fashioned reality give up this gift.

ZEO based view about time, state function reduction, and consciousness

In ZEO quantum measurement theory extends to a theory of consciousness: observer ceases to be an outsider and becomes part of the physical world also mathematically. The detailed discussion of various issues and of recent situation of TGD inspired theory of consciousness can be found in [L38].

The basic idea is that consciousness (actually not a property of anything) is in the state function reduction, between the two quantum realities rather than being a property of quantum reality. This resolves various problems of monistic and dualistic approaches, and one could say that TGD ontology is tri-partistic: classical existence at the space-time level (space-time surfaces), existence at quantum level (zero energy states), and conscious existence at the level of state function reductions. Adelic physics implies further division of realities to "real" and p-adic sectors serving as correlates for sensory and cognitive aspects of conscious experience.

The theory has developed slowly. ZEO meant breakthrough and led gradually through twists and turns to a notion of self surprisingly similar to the original idea. Negentropy maximization principle (NMP) was for a long time regarded as a separate principle but its statistical form follows automatically from adelic physics [L33, L35]. The understanding of the notion of time has been the main challenge.

The basic notion is that of self.

1. Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to repeated state function reductions leaving both the passive boundary of CD and the corresponding parts of zero energy states (state pairs) invariant. The parts of zero energy states at the active boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.

2. The first quantum jump to the opposite boundary corresponds to the act of "free will" or birth of re-incarnated self. Hence the act of "free will" changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means "death" of self and "re-incarnation" of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.

3. This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possible by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at the same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

4. It is important to notice that one has actually self hierarchy as a counterpart for the existence of hierarchy of systems. Sub-selves correspond to mental images of self, which in turn defines mental image of a higher level self. The proposal is that sub-selves of sub-self are experienced as averages. One might say that TGD predicts pan-psychism in well-defined sense.

   The new view about subsystem makes possible sharing of mental images by entanglement although selves are un-entangled at their own level and thus define separate conscious entities. The new view about subsystem follows naturally from the notion of many-sheeted space-time: space-time sheets can be disjoint although smaller space-time sheets glued to them by wormhole contacts with Euclidian signature of induced metric can have magnetic flux tube connections serving as correlates of attention.

It is clear that selves and their time reversals correspond to causality and retrocausality. Self experiences that signals arrive from geometric past always: the roles of past and future are however changed in the re-incarnation of self.

ZEO can be said to be time symmetric. There is however a breaking of time symmetry in the sense that the twistor lift TGD violates T (and also of CP and P) realized as a time reflection with respect to the center of CD [L21, L24]. An interesting question is whether this asymmetry could favor the second causal arrow in some sense. For instance, could the life cycles of self with standard arrow of time be considerably longer than those for time reversed selves? This would be due to T-non-invariance of the probabilities for the first reduction to the opposite boundary of CD. Could the longevity in standard time direction emerge in long length scales? For elementary particles the durations of selves are expected to be short since the usual rules for state function reduction apply to the reductions meaning death of self.

There are processes in which the arrow of time seems to be non-standard and a fascinating question is whether these ghostly time reversed selves could be observed, and whether even communications with them could be possible! Some people believe in communications between deceased and alive and study of the communications with deceased is part of parapsychology: could there be some seed of truth in these beliefs?

Possible implications and experimental support for retrocausality

Retrocausality implies that signals can propagate in both directions of time. The signals could even be time reflected at the boundary of CD, which would mean state function reduction changing the arrow of time in the case of signal (note that there is hierarchy of CDs and selves). These reflections could make possible apparently superluminal communications and communication with future and past.

1. The TGD based model for long term memories and precognition relies on the idea that memories involve time reflection from either boundary of CD [K81, ?, K106, K9].

   The model for motor actions as induced by signals sent to the brain of the geometric past relies on the same idea and explains Libet's strange finding that conscious action is preceded by neuronal activity [J4] used usually to argue that free will is illusion.

   Since the signals propagating to non-standard direction of time has negative energy, one can consider also a model of remote metabolism in which the system needing metabolic energy sends negative energy signal to a system able to provide it, say population reverted laser. This quantum credit card mechanism making possible instantaneous reactions would have obvious evolutionary value and would also favor co-operation.

2. Fantappie [J20] was probably the first theoretical physicist to propose that causal arrow might vary in in living matter and introduced the notion of syntropy, which would correspond entropy growing in nonstandard direction of time. There is quite a number of bio-systems which might be retrocausal at some level. One example is the self-assembly of bio-macromolecules (say tobacco mosaic virus): retrocausally a decay would be in question. Also phase conjugate laser beams [D3, D5] and phase conjugate sound waves are known to obey second law in wrong time direction. For some reason these empirical facts have not captured the attention of theoreticians. In ZEO these findings find a natural explanation.

3. The possibility of time reflection implies that light velocity ceases to be a barrier for communications. One can even speculate with the possibility that conscious entities in distant galaxies could communicate using this mechanism. The altered states of consciousness caused by various psychedelics involve often the experiences about encountering representatives of other civilizations and one can ask whether these encounters are due to remote sensory experiences based on the above mechanism involving both classical and quantum communication (entanglement) [L9] [K100, K97]. Could it be that some sensory receptors (perhaps all) are connections to magnetic flux tubes which can connect the brain to even remote galaxies? If this were the case, one must ask whether our ideas really originate in our brains.

4. One can even imagine that causal arrow is not definite in the sense that one can have quantum states, which are superpositions of states with opposite causal arrows, and there is even a claim that the existence of these states have been verified experimentally by quantum measuring the arrow of causality - causal witness is the name for this observable: see the article *Experimental verification of an indefinite causal order* by Rubio *et al* [B26](see `http://tinyurl.com/ltamjbv`). The popular article *"Causal Witness" Provides First Experimental*

Evidence Of Indefinite Causal Order (see http://tinyurl.com/lwaurk3) summarizes the work of Rubio *et al.*

If the finding is real it is revolutionary: in the standard physics framework it is very difficult to imagine how a superposition of different causal arrows could be possible. In the case of superposition of two causal orders the measurement of causal witness has two outcomes and both are claimed to be possible with certain probabilities.

Does TGD allow the superposition of causal arrows? One can obviously decompose the sub-WCW associated with given CD to sectors with well-defined causal arrow: they are related by time reflection T and are indeed different by T violation for classical dynamics. The roles of passive and active boundaries would be changed for the T-related sectors [L36] (see http://tinyurl.com/y9tgfxbf). Superposition of causal arrows would mean a state having component in both sectors. This makes sense if state function reduction to the opposite boundary is preceded by the measurement of the causal witness. Therefore the formation of this superposition and refusal to measure causal witness would be a recipe for immortality!

The localizations in the sequence of reductions to the active boundary must occur in complete synchrony for the components in the superposition if they occur at all. A stronger condition is that the two reduction sequences cease so that the time flows stop in both directions: there would be no observables commuting with the observables diagonalized at the passive boundary to be measured anymore [L38]. Does the absence of a well-defined causal arrow alone imply an experience of timelessness or must also the time flow stop? Could the enlightened states reported by meditators and involving experience of timelessness have something in common with this kind of states?

2.8 Still about the notion of causal indefiniteness in TGD framework

The motivation for this comment came from a popular article "*Quantum mischief rewrites the laws of cause and effect*" (https://cutt.ly/2xEP5Vd), which tells both about the theoretical work of Lucien Hardy [B37](https://arxiv.org/pdf/gr-qc/0509120.pdf) and related experimental work, in particular about the following experimental finding [?] (https://advances.sciencemag.org/content/3/3/e1602589.short.

Photon beam goes through a spin splitter to form a superposition of photons going along two paths. At the first path they go through A and then through B having some effect on the photons. At second splitter the order of A and B is changed. After that the beams are superposed and it is found that the photons in a causally indefinite state in the sense that the effects of both AB and BA are superposed. In classical physics this is impossible.

The finding is claimed to demonstrate causal indefiniteness: one does not know whether A causes B or B causes A. Classically - that is in the framework provided by fixed causal order dictated by Minkowski space - this seems to be the case.

Is this interpretation correct? Is one really forced to give up causality in the standard form? The rules of standard quantum theory are consistent with the finding but should one change the views about the notion of space-time?

2.8.1 Background

What happens to causality in quantum gravity?

Lightcone of M^4 characterizes the causal structure of Minkowski space in special relativity and is the basic notion of QFTs. In curved space-time of GRT, the light-cone however depends on the metric of space-time. Causal structure is dynamical. The intuitive view is that in quantum gravity causality becomes somehow fuzzy since there is no unique space-time anymore. What this non-uniqueness means is not clear. For instance, could it correspond to what happens in the path integral over space-times?

The problem is that one cannot compare the causal structure for different space-times because the light-cones characterizing them are in different space-times. If the space-times had common coordinates, the comparison would become possible but one cannot assume this.

Lucien Hardy wanted to understand what happens for causality in quantum gravity [B37]. Hardy proposed a method to test whether events in separate space-time regions are causally related.

1. The method allows to formulate dynamical causality operationally in terms of correlations for measurements performed for regions of space-time. He also introduces the notion of an elementary region from which more complex regions giving rise to causaloids are built. Elementary region corresponds to a space-time region in which some measurement giving a definite result is performed.

   One is interested in the correlations between measurement results associated with disjoint elementary regions and in principle all measurements should reduce to a deduction of such correlations. If two disjoint regions of this kind are causally correlated, the measurement outcomes are correlated. The basic interest is in the conditional probabilities for various outcomes from the measurement of observable F_2 in region R_2 given that the measurement outcome for F_1 in R_1 is known.

   Hardy calls these structures causaloids and proposes that causaloids can be composed to form larger causaloids. No fixed causal structure is assumed and even the notion of time is in principle un-necessary in this formulation for experimental deduction of causal structure. Hardy suggests that the quantization of gravity could be performed using the notion of causaloid.

Quantum switch

Second input comes from quantum computation. Giulio Chiribella and colleagues were interested on what kind of computations are possible [B22] (`https://cutt.ly/wxEJtDF`). Classical computation can be characterized as a recursive function mapping natural numbers to natural numbers. One can build more complex functions from given functions by composition of functions. In classical computation the functions are represented as networks of Boolean gates. In quantum computation the quantum gates are used. Now the situation is more complex, since the outcome of the computation is deduced from the probabilities for various outcomes emerging as the quantum computation halts.

Chiribella and colleagues asked what kind of functions are possible. They ended up with the notion of quantum switch. Beam splitter divides the incoming photon beam to two branches. For the first branch function BA is realizes and for the second branch function AB so that one can speak of two different causal orders. After this the beams superpose. If AB and BA can be realized as causal orders, one could say that the resulting state is causally indefinite. If AB and BA are interpreted as quantum computations wihtout halting one can say that quantum switch realizes a superposition of two computations.

The quantum switch can be realized in the laboratory for the first time by Giulia Rubino *et al* [B27](`https://cutt.ly/pxEH5wQ`. One can measure the polarization of the outgoing photons from the quantum switch to see whether the photons carry information about both AB and BA. This was found to be the case and the findings have been interpreted by saying that that photon experiences causal indefiniteness.

Several technological applications such as communication over noisy channels (`https://cutt.ly/2xEJfVB`) and quantum refrigerator based on indefinite causal order (ICO) (`https://cutt.ly/cxEJcj9`) have been proposed.

Hardy also proposes a Quantum Equivalence Principle [B38] stating that one can find a common reference frame for various deformations of a given space-time metric such that the light-cones of various space-time metrics coincide in these coordinates at least locally.

2.8.2 TGD view about indefiniteness

In the TGD framework [L59] the basic problem of quantum gravity due to the dynamical nature of causality disappears since the embedding space defines the pre-existing causal structure inducing the causal structure at space-time surfaces.

1. In the TGD framework the space-time of GRT is replaced with a 4-surface in $H = M^4 \times CP_2$. The topology of the space-time surface is non-trivial in all scales which leads to the notion of many-sheeted space-time allowing to reduce matter as shape to the space-time topology. Matter is not something in space-time but topological inhomogenities of space-time surface with size and shape - space-time sheets.

2. The basic conceptual problem in the quantization GRT is due to inability to compare different space-times, in particular their causal structures. This problem disappears in TGD.

   The fixed causal structure of Minkowski space M^4 defines the causal structure with induces causal structures of space-time surfaces in terms of induced metric. One can also quite concretely compare the light-cones of different space-time surfaces determined by the induced metric.

   One can also use M^4 linear coordinates as common coordinates for all space-time surfaces. If the space-time surface does not have 4-D M^4 projection, one can choose a subset of H-coordinates as space-time coordinates. By its maximal symmetries H allows very limited set of preferred coordinates sothat the problems produced by general coordinate invariance are circumvented.

   In TGD framework the surface property of space-time realizes the Quantum Equivalence Principle a at the level of embedding space in the same way as isometries of the space-time as source of conservation laws are lifted to the level of the embedding space.

3. In quantum TGD, also zero energy ontology (ZEO) and causal diamond (CD) are basic notions. CD represents the perceptive field of a conscious entity. The notion of CD resembles the notion of causaloid. One can assign a CD to any quantum system, even elementary particle. CDs form an analog of an atlas consisting of charts and there is a fractal hierarchy with CDs inside CDs, and also overlapping CDs.

4. Zero energy states inside CDs represent particle states as extended objects rather than points. Zero energy states associated with CD correspond to superpositions of space-time surfaces identifiable as preferred extremals of an action principle deriving from the twistor lift of TGD. Minimal surfaces, which are also extermals of so called Kähler action, are in question - minimal surface property geometrizes the notion of massless field and extrelality also for Kähler poses extremely powerful additional conditions guaranteeing Bohr orbit like character of the space-time surface needed to realize general coordinate invariance.

   The important point is that the configurations AB and BA appearing in quantum switch corresponds to a space-time surface represents a branching of 3-surfaces representing photon propagation to two pieces at beam splitter and recombination back to single 3-surface making it possible for the photon wave functions interfere. Causal indefiniteness in the proposed sense does *not* mean that the direction of the causal arrow as an arrow of time is changed and in TGD framework it is not natural to speak about causal indefiniteness.

5. Concerning the understanding of the causality at quantum level in TGD Universe, induction is the key notion. All geometric structures are induced from those of H. This applies to metric, spinor connection, spinor structure, and twistor structure.

   In particular, second quantized spinor field of H is a superposition of modes of the massless Dirac operator of H, which can be solved explicitly and one can calculate Dirac propagator [L61]. The induction of the second quantized spinor field means a restriction to space-time surface and propagators at space-time surface are simply propagators in H. There are no problems with causality since it is induced from H to space-time surfaces.

2.8.3 Also a genuine change of the arrow of time is possible in ZEO

TGD however predicts a different kind of causal anomaly: the arrow of time can change and induce the change of the thermo-dynamical arrow of time [L52].

1. TGD predicts that two kinds of fermionic vacua corresponding intuitively to Dirac seas for which either all negative energy states or positive energy states are filled. They are present also in QFTs but one selects only the second one.

The fermionic creation/annuhilation operators for the first vacuum act like annihilation/creation operators for the second vacuum. In ZEO these two fermionic vacua are associated with the opposite boundaries of CD.

2. Zero energy states as pairs of states assignable to the boundaries of CD. By conservation laws one can say that the total quantum numbers of CD vanish so that the total quantum numbers for the boundaries of CD are opposite.

3. In ZEO [L52, L71] there are two kinds of state function reductions (SFRs): "big" SFRs (BSFRs) as counterparts of ordinary SFRs and "small" SFRs (SSFRs) as counterparts of "weak" measurements as quantum analogs of classical measurements. In BSFRs the arrow of time changes and therefore cause and effect change their roles.

4. Either boundary of the CD is the passive boundary. Neither the passive boundary nor states at it change during the sequences of SSFRs. One can say that the Zeno effect is realized at the passive boundary.Active boundary recedes from the passive boundary in a sequence of scalings of CD followed by SSFRs preceded by unitary time evolutions. Therefore also the states at the active boundary change.

5. In BSFR the active boundary becomes passive and vice versa. The time reversal occurs for dark matter with $h_{eff} = nh_0$ residing at magnetic bodies, and since MB controls the dynamics of ordinary matter, BSFRs for MB induce effective change of the arrow of time for the ordinary matter in scales much longer than it would occur normally in BSFRs in the scale of microcosmos.

6. The change of the thermo-dynamical arrow of time changes in BSFR implies thermo-dynamical anomalies such as generation of gradients observed in systems with a reversed arrow of time [L51]. For instance, the time reversed system can effectively extract thermal energy from the environment. Actually this would be dissipation with a reversed arrow of time. Time reversal also makes self-organized quantum criticality (QSOC) possible [L130], and homeostasis could be seen as the biological manifestation of QSOC.

2.9 Appendix: A Generalization Of The Notion Of Embedding Space

In the following the recent view about structure of embedding space forced by the quantization of Planck constant is described. This view has developed much before the original version of this chapter was written.

The original idea was that the proposed modification of the embedding space could explain naturally phenomena like quantum Hall effect involving fractionization of quantum numbers like spin and charge. This does not however seem to be the case. $G_a \times G_b$ implies just the opposite if these quantum numbers are assigned with the symmetries of the embedding space. For instance, quantization unit for orbital angular momentum becomes n_a where Z_{n_a} is the maximal cyclic subgroup of G_a.

One can however imagine of obtaining fractionization at the level of embedding space for space-time sheets, which are analogous to multi-sheeted Riemann surfaces (say Riemann surfaces associated with $z^{1/n}$ since the rotation by 2π understood as a homotopy of M^4 lifted to the space-time sheet is a non-closed curve. Continuity requirement indeed allows fractionization of the orbital quantum numbers and color in this kind of situation.

2.9.1 Both Covering Spaces And Factor Spaces Are Possible

The observation above stimulates the question whether it might be possible in some sense to replace H or its factors by their multiple coverings.

1. This is certainly not possible for M^4, CP_2, or H since their fundamental groups are trivial. On the other hand, the fixing of quantization axes implies a selection of the sub-space $H_4 = M^2 \times S^2 \subset M^4 \times CP_2$, , where S^2 is a geodesic sphere of CP_2. $\hat{M}^4 = M^4 \backslash M^2$ and $\hat{CP}_2 =$

$CP_2\backslash S^2$ have fundamental group Z since the codimension of the excluded sub-manifold is equal to two and homotopically the situation is like that for a punctured plane. The exclusion of these sub-manifolds defined by the choice of quantization axes could naturally give rise to the desired situation.

2. Zero energy ontology forces to modify this picture somewhat. In zero energy ontology causal diamonds (CDs) defined as the intersections of future and past directed light-cones are loci for zero energy states containing positive and negative energy parts of state at the two light-cone boundaries. The location of CD in M^4 is arbitrary but p-adic length scale hypothesis suggests that the temporal distances between tips of CD come as powers of 2 using CP_2 size as unit. Thus M^4 is replaces by CD and $\hat{M}^4$ is replaced with $\hat{CD}$ defined in obvious manner.

3. H_4 represents a straight cosmic string inside CD. Quantum field theory phase corresponds to Jones inclusions with Jones index $\mathcal{M}:\mathcal{N}<4$. Stringy phase would by previous arguments correspond to $\mathcal{M}:\mathcal{N}=4$. Also these Jones inclusions are labeled by finite subgroups of $SO(3)$ and thus by Z_n identified as a maximal Abelian subgroup.

   One can argue that cosmic strings are not allowed in QFT phase. This would encourage the replacement $\hat{CD}\times \hat{CP}_2$ implying that surfaces in $CD\times S^2$ and $(M^2\cap CD)\times CP_2$ are not allowed. In particular, cosmic strings and CP_2 type extremals with M^4 projection in M^2 and thus light-like geodesic without zitterwebegung essential for massivation are forbidden. This brings in mind instability of Higgs=0 phase.

4. The covering spaces in question would correspond to the Cartesian products $\hat{CD}_{n_a}\times \hat{CP}_{2n_b}$ of the covering spaces of $\hat{CD}$ and $\hat{CP}_2$ by Z_{n_a} and Z_{n_b} with fundamental group is $Z_{n_a}\times Z_{n_b}$. One can also consider extension by replacing $M^2\cap CD$ and S^2 with its orbit under G_a (say tetrahedral, octahedral, or icosahedral group). The resulting space will be denoted by $\hat{CD}\hat{\times}G_a$ *resp.* $\hat{CP}_2\hat{\times}G_b$.

5. One expects the discrete subgroups of $SU(2)$ emerge naturally in this framework if one allows the action of these groups on the singular sub-manifolds $M^2\cap CD$ or S^2. This would replace the singular manifold with a set of its rotated copies in the case that the subgroups have genuinely 3-dimensional action (the subgroups which corresponds to exceptional groups in the ADE correspondence). For instance, in the case of $M^2\cap CD$ the quantization axes for angular momentum would be replaced by the set of quantization axes going through the vertices of tetrahedron, octahedron, or icosahedron. This would bring non-commutative homotopy groups into the picture in a natural manner.

6. Also the orbifolds $\hat{CD}/G_a\times \hat{CP}_2/G_b$ can be allowed as also the spaces $\hat{CD}/G_a\times(\hat{CP}_2\hat{\times}G_b)$ and $(\hat{CD}\hat{\times}G_a)\times \hat{CP}_2/G_b$. Hence the previous framework would generalize considerably by the allowance of both coset spaces and covering spaces.

There are several non-trivial questions related to the details of the gluing procedure and phase transition as motion of partonic 2-surface from one sector of the embedding space to another one.

1. How the gluing of copies of embedding space at $(M^2\cap CD)\times CP_2$ takes place? It would seem that the covariant metric of M^4 factor proportional to $\hbar^2$ must be discontinuous at the singular manifold since only in this manner the idea about different scaling factor of M^4 metric can make sense. This is consistent with the identical vanishing of Chern-Simons action in $M^2\times S^2$.

2. One might worry whether the phase transition changing Planck constant means an instantaneous change of the size of partonic 2-surface in CD degrees of freedom. This is not the case. Light-likeness in $(M^2\cap CD)\times S^2$ makes sense only for surfaces $X^1\times D^2\subset(M^2\cap CD)\times S^2$, where X^1 is light-like geodesic. The requirement that the partonic 2-surface X^2 moving from one sector of H to another one is light-like at $(M^2\cap CD)\times S^2$ irrespective of the value of Planck constant requires that X^2 has single point of $(M^2\cap CD)$ as M^2 projection. Hence no sudden change of the size X^2 occurs.

3. A natural question is whether the phase transition changing the value of Planck constant can occur purely classically or whether it is analogous to quantum tunnelling. Classical non-vacuum extremals of Chern-Simons action have two-dimensional CP_2 projection to homologically non-trivial geodesic sphere S^2_I. The deformation of the entire S^2_I to homologically trivial geodesic sphere S^2_{II} is not possible so that only combinations of partonic 2-surfaces with vanishing total homology charge (Kähler magnetic charge) can in principle move from sector to another one, and this process involves fusion of these 2-surfaces such that CP_2 projection becomes single homologically trivial 2-surface. A piece of a non-trivial geodesic sphere S^2_I of CP_2 can be deformed to that of S^2_{II} using 2-dimensional homotopy flattening the piece of S^2 to curve. If this homotopy cannot be chosen to be light-like, the phase transitions changing Planck constant take place only via quantum tunnelling. Obviously the notions of light-like homotopies (cobordisms) and classical light-like homotopies (cobordisms) are very relevant for the understanding of phase transitions changing Planck constant.

2.9.2 Do Factor Spaces And Coverings Correspond To The Two Kinds Of Jones Inclusions?

What could be the interpretation of these two kinds of spaces?

1. Jones inclusions appear in two varieties corresponding to $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$ and one can assign a hierarchy of subgroups of $SU(2)$ with both of them. In particular, their maximal Abelian subgroups Z_n label these inclusions. The interpretation of Z_n as invariance group is natural for $\mathcal{M} : \mathcal{N} < 4$ and it naturally corresponds to the coset spaces. For $\mathcal{M} : \mathcal{N} = 4$ the interpretation of Z_n has remained open. Obviously the interpretation of Z_n as the homology group defining covering would be natural.

2. $\mathcal{M} : \mathcal{N} = 4$ should correspond to the allowance of cosmic strings and other analogous objects. Does the introduction of the covering spaces bring in cosmic strings in some controlled manner? Formally the subgroup of $SU(2)$ defining the inclusion is $SU(2)$ would mean that states are $SU(2)$ singlets which is something non-physical. For covering spaces one would however obtain the degrees of freedom associated with the discrete fiber and the degrees of freedom in question would not disappear completely and would be characterized by the discrete subgroup of $SU(2)$.

   For anyons the non-trivial homotopy of plane brings in non-trivial connection with a flat curvature and the non-trivial dynamics of topological QFTs. Also now one might expect similar non-trivial contribution to appear in the spinor connection of $\hat{CD}\hat{\times}G_a$ and $\hat{CP_2}\hat{\times}G_b$. In conformal field theory models non-trivial monodromy would correspond to the presence of punctures in plane.

3. For factor spaces the unit for quantum numbers like orbital angular momentum is multiplied by n_a *resp.* n_b and for coverings it is divided by this number. These two kind of spaces are in a well defined sense obtained by multiplying and dividing the factors of $\hat{H}$ by G_a *resp.* G_b and multiplication and division are expected to relate to Jones inclusions with $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$, which both are labeled by a subset of discrete subgroups of SU(2).

4. The discrete subgroups of $SU(2)$ with fixed quantization axes possess a well defined multiplication with product defined as the group generated by forming all possible products of group elements as elements of $SU(2)$. This product is commutative and all elements are idempotent and thus analogous to projectors. Trivial group G_1, two-element group G_2 consisting of reflection and identity, the cyclic groups Z_p, p prime, and tetrahedral, octahedral, and icosahedral groups are the generators of this algebra.

By commutativity one can regard this algebra as an 11-dimensional module having natural numbers as coefficients ("rig"). The trivial group G_1, two-element group G_2¡ generated by reflection, and tetrahedral, octahedral, and icosahedral groups define 5 generating elements for this algebra. The products of groups other than trivial group define 10 units for this algebra so that there are 11 units altogether. The groups Z_p generate a structure analogous to natural numbers acting as analog of coefficients of this structure. Clearly, one has effectively 11-dimensional commutative algebra in 1-1 correspondence with the 11-dimensional "half-lattice" N^{11} (N denotes natural numbers). Leaving away reflections, one obtains N^7. The projector representation suggests a connection with Jones inclusions. An interesting question concerns the possible Jones inclusions assignable to the subgroups containing infinitely manner elements. Reader has of course already asked whether dimensions 11, 7 and their difference 4 might relate somehow to the mathematical structures of M-theory with 7 compactified dimensions. One could introduce generalized WCW spinor fields in the WCW labelled by sectors of H with given quantization axes. By introducing Fourier transform in N^{11} one would formally obtain an infinite-component field in 11-D space.

The question how do the Planck constants associated with factors and coverings relate is far from trivial and I have considered several options.

1. If one assumes that $\hbar^2(X)$, $X = M^4$, CP_2 corresponds to the scaling of the covariant metric tensor g_{ij} and performs an over-all scaling of metric allowed by Weyl invariance of Kähler action by dividing metric with $\hbar^2(CP_2)$, one obtains $r^2 \equiv \hbar^2/\hbar_0^2\hbar^2(M^4)/\hbar^2(CP_2)$. This puts M^4 and CP_2 in a very symmetric role and allows much more flexibility in the identification of symmetries associated with large Planck constant phases.

2. Algebraist would argue that Planck constant must define a homomorphism respecting multiplication and division (when possible) by G_i. This requires $r(X) = \hbar(X)\hbar_0 = n$ for covering and $r(X) = 1/n$ for factor space or vice versa. This gives two options.

3. Option I: $r(X) = n$ for covering and $r(X) = 1/n$ for factor space gives $r \equiv \hbar/\hbar_0 = r(M^4)/r(CP_2)$. This gives $r = n_a/n_b$ for $\hat{H}/G_a \times G_b$ option and $r = n_b/n_a$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for hybrid cases.

4. Option II: $r(X) = 1/n$ for covering and $r(X) = n$ for factor space gives $r = r(CP_2)/r(M^4)$. This gives $r = n_b/n_a$ for $\hat{H}/G_a \times G_b$ option and $r = n_a/n_b$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for the hybrid cases.

5. At quantum level the fractionization would come from the modification of fermionic anti-commutation (bosonic commutation) relations involving $\hbar$ at the right hand side so that particle number becomes a multiple of $1/n$ or n. If one postulates that the total number states is invariant in the transition, the increase in the number of sheets is compensated by the increase of the fundamental phase space volume proportional to $\hbar$. This would give $r(X) \to r(X)/n$ for factor space and $r(X) \to nr(X)$ for the covering space to compensate the n-fold reduction/increase of states. This would favor Option II.

6. The second manner to distinguish between these two options is to apply the theory to concrete physical situations. Since G_a and G_b act as symmetries in CD and CP_2 degrees of freedom, one might of being able to distinguish between the two options if it is possible to distinguish between the action of G as symmetry of quantum states associated with covering and factor space. Also the quantization of the orbital spin quantum number at single particle level as multiples of n can be distinguished from that in multiples of $1/n$.

2.9.3 A Simple Model Of Fractional Quantum Hall Effect

The generalization of the embedding space suggests that it could possible to understand fractional quantum Hall effect [D1] at the level of basic quantum TGD. This section represents the first rough model of QHE constructed for a couple of years ago is discussed. Needless to emphasize, the model represents only the basic idea and involves ad hoc assumption about charge fractionization.

Recall that the formula for the quantized Hall conductance is given by

$$\begin{aligned} \sigma &= \nu \times \frac{e^2}{h} \ , \\ \nu &= \frac{n}{m} \ . \end{aligned} \tag{2.9.1}$$

Series of fractions in $\nu = 1/3, 2/5, 3/7, 4/9, 5/11, 6/13, 7/15..., 2/3, 3/5, 4/7, 5/9, 6/11, 7/13..., 5/3, 8/5, 11/7, 14/9...4/3, 7/5$ $1/5, 2/9, 3/13..., 2/7, 3/11..., 1/7....$ with odd denominator have been observed as are also $\nu = 1/2$ and $\nu = 5/2$ states with even denominator [D1].

The model of Laughlin [D14] cannot explain all aspects of FQHE. The best existing model proposed originally by Jain is based on composite fermions resulting as bound states of electron and even number of magnetic flux quanta [D10]. Electrons remain integer charged but due to the effective magnetic field electrons appear to have fractional charges. Composite fermion picture predicts all the observed fractions and also their relative intensities and the order in which they appear as the quality of sample improves.

The generalization of the notion of embedding space suggests the possibility to interpret these states in terms of fractionized charge, spin, and electron number. There are four combinations of covering and factors spaces of CP_2 and three of them can lead to the increase of Planck constant. Besides this there are two options for the formula of Planck constant so that which the very meager theoretical background one can make only guesses. On the following just for fun consideration option I is considered although the conservation of number of states in the phase transition changing $\hbar$ favors option II.

1. The easiest manner to understand the observed fractions is by assuming that both M^4 and CP_2 correspond to covering spaces so that both spin and electric charge and fermion number are fractionized. This means that e in electronic charge density is replaced with fractional charge. Quantized magnetic flux is proportional to e and the question is whether also here fractional charge appears. Assume that this does not occur.

2. With this assumption the expression for the Planck constant becomes for Option II as $r = \hbar/\hbar_0 = n_a/n_b$ and charge and spin units are equal to $1/n_b$ and $1/n_a$ respectively. This gives $\nu = nn_a/n_b$. The values $m = 2, 3, 5, 7, ..$ are observed. Planck constant can have arbitrarily large values. There are general arguments stating that also spin is fractionized in FQHE.

3. The appearance of $\nu = 5/2$ has been observed [D8]. The fractionized charge is $e/4$ in this case. Since $n_i > 3$ holds true if coverings are correlates for Jones inclusions, this requires to $n_b = 4$ and $n_a = 10$. n_b predicting a correct fractionization of charge. The alternative option would be $n_b = 2$ that also Z_2 would appear as the fundamental group of the covering space. Filling fraction $1/2$ corresponds in the composite fermion model and also experimentally to the limit of zero magnetic field [D10]. $n_b = 2$ is however inconsistent with the observed fractionization of electric charge and with the vision inspired by Jones inclusions.

4. A possible problematic aspect of the TGD based model is the experimental absence of even values of n_b except $n_b = 2$ (Laughlin's model predicts only odd values of n). A possible explanation is that by some symmetry condition possibly related to fermionic statistics (as in Laughlin model) n_a/n_b must reduce to a rational with an odd denominator for $n_b > 2$. In other words, one has $n_a \propto 2^r$, where 2^r the largest power of 2 divisor of n_b.

5. Large values of n_a emerge as B increases. This can be understood from flux quantization. One has $e\int BdS = n\hbar(M^4) = nn_a\hbar_0$. By using actual fractional charge $e_F = e/n_b$ in the flux factor would give $e_F \int BdS = n(n_a/n_b)\hbar_0 = n\hbar$. The interpretation is that each of the n_a sheets contributes one unit to the flux for e. Note that the value of magnetic field in given sheet is not affected so that the build-up of multiple covering seems to keep magnetic field strength below critical value.

6. The understanding of the thermal stability is not trivial. The original FQHE was observed in 80 mK temperature corresponding roughly to a thermal energy of $T \sim 10^{-5}$ eV. For graphene the effect is observed at room temperature. Cyclotron energy for electron is (from $f_e = 6\times10^5$ Hz at $B = .2$ Gauss) of order thermal energy at room temperature in a magnetic field varying in the range 1-10 Tesla. This raises the question why the original FQHE requires so low temperature. The magnetic energy of a flux tube of length L is by flux quantization roughly $e^2B^2S \sim E_c(e)m_eL$ ($\hbar_0 = c = 1$) and exceeds cyclotron roughly by a factor L/L_e, L_e electron Compton length so that thermal stability of magnetic flux quanta is not the explanation. A possible explanation is that since FQHE involves several values of Planck constant, it is quantum critical phenomenon and is characterized by a critical temperature. The differences of the energies associated with the phase with ordinary Planck constant and phases with different Planck constant would characterize the transition temperature.

As already noticed, it is possible to imagine several other options and the identification of charge unit is rather ad hoc. Therefore this model can be taken only as a warm-up exercise. In [K72] Quantum Hall effect and charge fractionization are discussed in detail and one ends up with a rather detailed view about the delicacies of the Kähler structure of generalized embedding space.

Chapter 3

DNA as Topological Quantum Computer

3.1 Introduction

Large values of Planck constant makes possible all kinds of quantum computations [B5, B46, B11, B45]. What makes topological quantum computation (TQC) [B23, B43, B36, B28, B8] so attractive is that the computational operations are very robust and there are hopes that external perturbations do not spoil the quantum coherence in this case. The basic problem is how to create, detect, and control the dark matter with large $\hbar$. The natural looking strategy would be to assume that living matter, say a system consisting of DNA and cell membranes, performs TQC and to look for consequences.

There are many questions. How the TQC could be performed? Does TQC hypothesis might allow to understand the structure of living cell at a deeper level? What does this hypothesis predict about DNA itself? One of the challenges is to fuse the vision about living system as a conscious hologram with the DNA as TQC vision. The experimental findings of Peter Gariaev [I63, I74] might provide a breakthrough in this respect. In particular, the very simple experiment in which one irradiates DNA sample using ordinary light in UV-IR range and photographs the scattered light seems to allow an interpretation as providing a photograph of magnetic flux tubes containing dark matter. If this is really the case, then the bottle neck problem of how to make dark matter visible and how to manipulate it would have been resolved in principle. The experiment of Gariaev and collaborators [I74] also show that the photographs are obtained only in the presence of DNA sample. This leaves open the question whether the magnetic flux tubes associated with instruments are there in absence of DNA and only made visible by DNA or generated by the presence of DNA.

3.1.1 Basic Ideas Of TQC

The basic idea of topological quantum computation (TQC) is to code TQC programs to braiding patterns (analogous to linking and knotting). A nice metaphor for TQC is as dance. Dancing pattern in time direction defines the TQC program. This kind of patterns are defined by any objects moving around so that the Universe might be performing topological quantum computation like activities in all scales.

One assigns to the strands of the braid elementary particles. The S-matrix coding for TQC is determined by purely topological consideration as a representation for braiding operation. It is essential that the particles are in anyonic phase: this means in TGD framework that the value of Planck constant differs from its standard value. Tqc as any quantum computation halts in state function reduction which corresponds to the measurement of say spins of the particles involved.

As in the case of ordinary computers one can reduce the hardware to basic gates. The basic 2-gate is represented by a purely topological operation in which two neighboring braid strands are twisted by π. 1-particle gate corresponds to a phase multiplication of the quantum state associated with braid strand. This operation is not purely topological and requires large Planck constant to overcome the effects of thermal noise.

In TGD framework TQC differs somewhat from the ordinary one.

1. Zero energy ontology (ZEO) means that physical states decompose into pairs of positive and negative energy states at the "upper" and "lower" light-like boundaries boundaries of $CD \times CP_2$, where CD denotes causal diamond identified as the intersection of the future and past directed light-cones (in the sequel CD is used for $CD \times CP_2$ in order to make notations more elegant). Positive and negative energy states have opposite values of conserved quantum numbers. The interpretation is as an event, say particle scattering, in positive energy ontology. The time like entanglement coefficients define S-matrix, or rather M-matrix, and this matrix can be interpreted as coding for physical laws in the structure of physical state as quantum superposition of statements "A implies B" with A and B represented as positive and negative energy parts of quantum state. The halting of topological quantum computation would select this kind of statement.

2. The new view about quantum state as essentially 4-D notion implies that the outcome of TQC is expressed as a four-dimensional pattern at space-time sheet rather than as time=constant final state. All kinds of patterns would provide a representation of this kind. In particular, holograms formed by large $\hbar$ photons emitted by Josephson currents, including EEG as a special case, would define particular kind of representation of outcome.

3.1.2 Identification Of Hardware Of TQC And TQC Programs

One challenge is to identify the hardware of TQC and realization of TQC programs.

1. Living cell is an excellent candidate in this respect. The lipid layers of the cell membrane is 2-D liquid crystal and the 2-D motion of lipids would define naturally the braiding if the lipids are connected to DNA nucleotides. This motion might be induced by the self organization patterns of metabolically driven liquid flow in the vicinity of lipid layer both in interior and exterior of cell membrane and thus self-organization patters of the water flow would define the TQC programs.

2. This identification of braiding implies that TQC as dancing pattern is coded automatically to memory in the sense that lipids connected to nucleotides are like dancers whose feet are connected to the wall of the dancing hall define automatically space-like braiding as the threads connected to their feet get braided. This braiding would define universal memory realized not only as tissue memory but related also to water memory [**?**].

3. It is natural to require that the genetic code is somehow represented as property of braids strands. This is achieved if strands are "colored" so that A,T,C,G correspond to four different "colors". This leads to the hypothesis that flux tubes assignable to nucleotides are wormhole magnetic flux tubes such that the ends of the two sheets carry quark and antiquark (*resp.* antiquark and quark) quantum numbers. This gives mapping A,T,C,G to u, u_c, d, d_c. These quarks are not ordinary quarks but their scaled variants predicted by the fractal hierarchy of color and electro-weak physics. Chiral selection in living matter could be explained by the hierarchy of weak physics. The findings of topologist Barbara Shipman about mathematical structure of honeybee dance led her to proposed that the color symmetries of quarks are in some mysterious way involved with honeybee cognition and this model would justify her intuition [A5].

4. One should identify the representation of qubit. Ordinary spin is not optimal since the representation of 1-gates would require a modification of direction of magnetic field in turn requiring modification of direction of flux tubes. A more elegant representation is based on quark color which means effectively 3-valued logic: true, false, and undefined, also used in ordinary computers and is natural in a situation in which information is only partial. In this case 1-gates would correspond to color rotations for space-time sheets requiring no rotation of the magnetic field.

In this framework genes define the hardware of TQC rather than genetic programs. This means that the evolution takes place also at the level of TQC programs meaning that strict genetic determinism fails. There are also good reasons to believe that these TQC programs can be inherited to some degree. This could explain the huge differences between us and our cousins in spite of almost the identical genetic codes and explains also cultural evolution and the observation that our children seem to learn more easily those things that we have already learned [I86]. It must be added that DNA as TQC paradigm seems to generalizedDNA, lipids, proteins, water molecules,... can have flux tubes connecting them together and this is enough to generate braidings and TQC programs. Even water could be performing simple TQC or at least building memory representations based on braiding of flux tubes connecting water molecules.

3.1.3 How Much TQC Resembles Ordinary Computation?

If God made us to his own image one can ask whether we made computers images of ourselves in some respects. Taking this seriously one ends up asking whether facts familiar to us from ordinary computers and world wide web might have counterparts in DNA as TQC paradigm.

1. Can one identify program files as space-like braiding patterns. Can one differentiate between program files and data files?

2. In ordinary computers electromagnetic signalling is in key role. The vision about living matter as conscious holograms suggests that this is the case also now. In particular, the idea that entire biosphere forms a TQC web communicating electromagnetically information and control signals looks natural. Topological light rays (MEs) make possible precisely targeted communications with light velocity without any change in pulse shape. Gariaev's findings [I63] that the irradiation of DNA by laser light induces emission of radio wave photons having biological effects on living matter at distances of tens of kilometers supports this kind of picture. Also the model of EEG in which the magnetic body controls the biological body also from astrophysical distances conforms with this picture.

3. The calling of computer programs by simply clicking the icon or typing the name of program followed by return is an extremely economic ways to initiate complex computer programs. This also means that one can construct arbitrarily complex combinations from given basic modules and call this complex by a single name if the modules are able to call each other. This kind of program call mechanism could be realized at the level of TQC by DNA. Since the intronic portion of genome increases with the evolutionary level and is about 98 per cent for humans, one can ask whether introns would contain representations for names of program modules. If so, introns would express themselves electromagnetically by transcribing the nucleotide to a temporal pattern of electromagnetic radiation activating desired subprogram call, presumably the conjugate of intronic portion as DNA sequence. A hierarchical sequence of subprogram calls proceeding downwards at intronic level and eventually activating the TQC program leading to gene expression is suggestive.

   [I63] [I63] has found that laser radiation scattering from given DNA activates only genomes which contain an address coded as temporal pattern for the direction of polarization plane. If flux tubes are super-conducting and there is strong parity breaking (chiral selection) then Faraday rotation for photons traveling through the wormhole flux tube code nucleotide to an angle characterizing the rotation of polarization plane. User id and password would be kind of immune system against externally induced gene expression.

4. Could nerve pulses establish only the connection between receiver and sender neurons as long magnetic flux tubes? Real communication would take place by electromagnetic signals along the flux tube, using topological light ray (ME) attached to flux tube, and by entanglement. Could neural transmitters specify which parts of genomes are in contact and thus serve as a kind of directory address inside the receiving genome?

3.1.4 Basic Predictions Of DNA As TQC Hypothesis

DNA as TQC hypothesis leads to several testable predictions about DNA itself.

Anomalous em charge

The model for DNA as TQC assigns to flux tubes starting from DNA an anomalous em charge. This means that the total charge of DNA nucleotide using e as unit is $Q = -2 + Q(q)$, where -2 is the charge of phosphate group and $Q(q) = -/+2/3, +/-1/3$ is the electromagnetic charge of quark associated with "upper" sheet of wormhole magnetic flux tube. If the phosphate group is not present one has $Q = Q(q)$. In the presence of phosphate bonds the anomalous charge makes possible the coding of nucleotides to the rotation of angle of polarization plane resulting as photon travels along magnetic flux tube. The anomalous em charge should be visible as an anomalous voltage created by DNA. It would be relatively easy to test this prediction by using various kinds of DNA:s.

Does breaking of matter antimatter and isospin symmetries happen at the level of DNA and mRNA?

The nice feature of the model is that it allows to interpret the slightly broken A-G and T-C symmetries of genetic code with respect to the third nucleotide Z of codon XYZ in terms of the analog of strong isospin symmetry at quark level at wormhole magnetic flux tubes. Also matter-antimatter dichotomy has a chemical analog in the sense that if the letter Y of codon corresponds to quark u, d (antiquark u_c, d_c), the codon codes for hydrophobic (hydrophilic) amino-acid. It is also known that the first letter X of the codon codes for the reaction path leading from a precursor to an amino-acid. These facts play a key role in the model for code of protein folding and catalysis. The basic assumption generalizing base pairing for DNA nucleotides is that wormhole flux tubes can connect an amino-acid inside protein only to molecules (amino-acids, DNA, mRNA, or tRNA) for which Y letter is conjugate to that associated with the amino-acid. This means that the reduction of Planck constant leading to the shortening of the flux tube can bring only these amino-acids together so that only these molecules can find each other in biocatalysis: this would mean kind of code of bio-catalysis.

The fact that matter-antimatter and isospin symmetries are broken in Nature suggests that the same occurs at the level of DNA for quarks and anti-quarks coding for nucleotides. One would expect that genes and other parts of genome differ in the sense that the anomalous em charge, isospin, and net quark number (vanishes for matter antimatter symmetric situation) differ for them. From Wikipedia [I91] one learns that there are rules about distribution of nucleotides which cannot be understood on basis of chemistry. The rules could be understood in terms of new physics. Chargaff's rules state that these symmetries hold true in one per cent approximation at the level of entire chromosomes. Szybalski's rules [I91] state that they fail for genes. There is also a rule stating that in good approximation both strands contain the same portion of DNA transcribed to mRNA. This implies that at mRNA level the sign of matter antimatter asymmetry is always the same: this is analogous to the breaking of matter antimatter asymmetry in cosmology (only matter is observed).

It would be interesting to study systematically the breaking of these symmetries for a sufficiently large sample of genes and also other in parts of genome where a compensating symmetry breaking must occur. That the irradiation of DNA by laser light induces emission of radio wave photons having biological effects on living matter at distances of tens of kilometers supports this kind of picture. Also the model of EEG in which magnetic body controls biological body from astrophysical distances conforms with this picture.

It must be emphasized that this model of DNA as TQC is only one possibility. There is large flexibility concerning the identification of fermions involved. For instance A,T,C,G could be represented also in terms of 4 states assignable to two spin half fermions at parallel flux tubes. This would give rise to high T_c superconductor with both $S = 0$ ($S = 1$) Cooper pairs assignet to flux tubes with opposite (parallel) magnetic fields. The spin-spin interaction energy for the Cooper pair would be negative and proportional to h_{eff} and same for all fermion pairs if $h_{eff} = h_{gr}$ hypothesis holds true at microscopic level.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L6].

3.2 Basic Concepts And Ideas

The following represents a brief overall view about the notions of quantum jump, unitary process described by unitary U-matrix between zero energy states having as its orthogonal rows M-matrices between positive and negative energy parts of zero energy states identifiable as counterpart of ordinary S-matrix and of Negentropy Maximization Principle (NMP) governing the dynamics of state function reduction cascade.

3.2.1 What Happens In Quantum Jump?

Quantum jump involves U process and state function reduction cascade. Negentropy Maximization Principle implies second law for the standard view about state function reduction: second law states that the ensemble entropy increases by the randomness of the outcome of the state function reduction process. When negentropic entanglement possible in what might be called intersection of the real and various p-adic worlds is present the situation is not so clear. Before proceeding to consider the modification of the second law one must define more precisely what U process is.

The simplest view about quantum jump is as a unitary U-process followed by as a cascade of state function reductions proceeding from top to bottom. But what is the top?

1. In positive energy ontology it would be entire Universe. Quantum classical correspondence suggests that one should be able to assign to quantum jump a duration of geometric time. For this proposal this time is most naturally infinite.

2. The vision about fractal hierarchy of selves and quantum jumps together with ZEO suggests a more refined view about quantum jump in which. U-process and subsequent state function reduction cascade could occur independently for disjoint CDs. For a given CD the new sub-CDs (representing mental images of the corresponding self) can be created and old destroyed so that the only constraint would be that only disjoint CDs can perform quantum jumps independently. For this option the duration of geometric time assignable to the quantum jump would naturally correspond to the temporal distance between the tips of CD: p-adic length scale hypothesis and number theoretical vision suggest that this distance comes as an octave of CP_2 time scale (prime or integer multiple is the more general option). For infinitely large CD this would mean infinite duration. This picture is consistent with the TGD view about how the arrow of subjective time induces the arrow of geometric time [K9].

3.2.2 M-Matrix

The unitary U-matrix characterizing the unitary process has as its rows orthogonal M-matrices characterized by in general non-unitarity M-matrices. M-matrix decomposes into a product of positive definite diagonal square roots of density matrix and unitary S-matrix measurement in particle physics experiment. M-matrix represents both the time-like entanglement between positive and negative energy parts of zero energy states with opposite quantum numbers and space-like entanglement for the positive and negative energy states.

Time-like and space-like entanglement in zero energy ontology

M-matrix for each summand is product of Hermitian square root of density matrix and unitary S-matrix multiplied by a square root of probability having interpretation as analog for Boltzmann weight or probability defined by density matrix (note that it is essential to have $Tr(Id) = 1$ for factors of type II_1. If factor of type I_∞ are present situation is more complex. This means that quantum computations are highly universal and M-matrices are characterized by the inclusion $\mathcal{N} \subset \mathcal{M}$ in each summand defining measurement resolution. Hermitian elements of $\mathcal{N}$ act as symmetries of M-matrix. The identification of the reducible entanglement characterized by Boltzmann weight like parameters in terms of thermal equilibrium would allow to interpret quantum theory as square root of thermodynamics.

If the entanglement probabilities defined by S-matrix and assignable to $\mathcal{N}$ rays do not belong to the algebraic extension used then a full state function reduction is prevented by NMP. Ff the generalized Boltzmann weights are also algebraic then also thermal entanglement is irreducible. In p-adic thermodynamics for Virasoro generator L_0 and using some cutoff for conformal weights the Boltzmann weights are rational numbers expressible using powers of p-adic prime p.

Effects of finite temperature

Usually finite temperature is seen as a problem for quantum computation. In TGD framework the effect of finite temperature is to replace zero energy states formed as pairs of positive and negative energy states with a superposition in which energy varies.

One has an ensemble of space-time sheets which should represent nearly replicas of the quantum computation. There are two cases to be considered.

1. If the thermal entanglement is reducible then each space-time sheet gives outcome corresponding to a well defined energy and one must form an average over these outcomes.

2. If thermal entanglement is irreducible each space-time sheet corresponds to a quantum superposition of space-time sheets, and if the outcome is represented classically as rates and temporal field patterns, it should reflect thermal average of the outcomes as such.

If the degrees of freedom assignable to topological quantum computation do not depend on the energy of the state, thermal width does not affect at all the relevant probabilities. The probabilities are actually affected even in the case of TQC since 1-gates are not purely topological and the effects of temperature in spin degrees of freedom are unavoidable. If T grows the probability distribution for the outcomes flattens and it becomes difficult to select the desired outcome as that appearing with the maximal probability.

3.2.3 About NMP And Quantum Jump

NMP is assumed to be the variational principle telling what can happen in quantum jump and says that the information content of conscious experience for the entire system is maximized. In zero energy ontology (ZEO) the definition of NMP is far from trivial and the recent progress - as I believe - in the understanding of structure of quantum jump forces to check carefully the details related to NMP. A very intimate connection between quantum criticality, life as something in the intersection of realities and p-adicities, hierarchy of effective values of Planck constant, negentropic entanglement (NE), and p-adic view about cognition emerges. One ends up also with an argument why p-adic sector is necessary if one wants to speak about conscious information. I will proceed by making questions.

What happens in single state function reduction?

State function reduction is a measurement of density matrix. The condition that a measurement of density matrix takes place implies standard measurement theory on both real and p-adic sectors: system ends to an *eigen-space* of density matrix. This is true in both real and p-adic sectors. NMP is stronger principle at the real side and implies state function reduction to 1-D subspace - its eigenstate.

The resulting N-dimensional space has however rational entanglement probabilities $p = 1/N$ so that one can say that it is the intersection of realities and p-adicities. If the number theoretic variant of entanglement entropy is used as a measure for the amount of entropy carried by entanglement rather than either entangled system, the state carries genuine information and is stable with respect to NMP if the p-adic prime p divides N. NMP allows only single p-adic prime for real $\rightarrow$ p-adic transition: the power of this prime appears is the largest power of prime appearing in the prime decomposition of N. Degeneracy means also criticality so that ordinary quantum measurement theory for the density matrix favors criticality and NMP fixes the p-adic prime uniquely.

If one - contrary to the above conclusion - assumes that NMP holds true in the entire p-adic sector, NMP gives in p-adic sector rise to a *reduction* of the negentropy in state function reduction if the original situation is negentropic and the eigen-spaces of the density matrix are 1-dimensional. This situation is avoided if one assumes that state function reduction cascade in real or genuinely p-adic sector occurs first (without NMP) and gives therefore rise to N-dimensional eigen spaces. The state is negentropic and stable if the p-adic prime p divides N. Negentropy is generated.

The real state can be transformed to a p-adic one in quantum jump (defining cognitive map) if the entanglement coefficients are rational or belong to an algebraic extension of p-adic numbers in the case that algebraic extension of p-adic numbers is allowed (number theoretic evolution gradually generates them). The density matrix can be expressed as sum of projection operators multiplied by probabilities for the projection to the corresponding sub-spaces. After state function reduction cascade the probabilities are rational numbers of form $p = 1/N$.

Number theoretic entanglement entropy also allows to avoid some objections related to fermionic and bosonic statistics. Fermionic and bosonic statistics require complete anti-symmetrization/symmetriza This implies entanglement which cannot be reduced away. By looking for symmetrized or antisymmetrized 2-particle state consisting of spin 1/2 fermions as the simplest example one finds that the density matrix for either particle is the simply unit 2×2 matrix. This is stable under NMP based on number theoretic negentropy. One expects that the same result holds true in the general case. The interpretation would be that particle symmetrization/antisymmetrization carries negentropy.

The degeneracy of the density matrix is of course not a generic phenomenon and one can argue that it corresponds to some very special kind of physics. The identification of space-time correlates for the hierarchy for the effective values $\hbar_{eff} = n\hbar$ of Planck constant as n-furcations of space-time sheet suggests strongly the identification of this physics in terms of this hierarchy. Hence quantum criticality, the essence of life as something in the rational intersection of realities and p-adicities, the hierarchy of effective values of $\hbar$, negentropic quantum entanglement, and the possibility to make real-p-adic transitions and thus cognition and intentionality would be very intimately related. This is a highly satisfactory outcome, since these ideas have been rather loosely related hitherto.

What happens in quantum jump?

Suppose that everything can be reduced to what happens for a given CD characterized by a scale. There are at least two questions to be answered.

1. There are two processes involved. State function reduction and quantum jump transforming real state to p-adic state (matter to cognition) and vice versa (intention to action). Do these transitions occur independently or not? Does the ordering of the processes matter? It has turned out that the mathematical realization of this picture is very difficult and that these transformations are not even needed in the adelic vision where cognitionandsensory aspects realized as p-adic and real space-time sheets are both present in all scales.

2. State function reduction cascade in turn consists of two different kinds of state function reductions. The M-matrix characterizing the zero energy state is product of square root of density matrix and of unitary S-matrix and the first step means the measurement of the projection operator. It defines a density matrix for both upper and lower boundary of CD and these density matrices are essentially same.

   (a) At the first step a measurement of the density matrix between positive and negative energy parts of the quantum state takes place for CD. One can regard both the lower and upper boundary as an eigenstate of density matrix in absence of NE. The measurement is thus completely symmetric with respect to the boundaries of CDs. At the real sector this leads to a 1-D eigen-space of density matrix if NMP holds true. In the intersection of real and p-adic sectors this need not be the case if the eigenvalues of the density matrix have degeneracy. Zero energy state becomes stable against further state function reductions! The interactions with the external world can of course destroy the stability sooner or later. An interesting question is whether so called higher states of consciousness relate to this kind of states.

   (b) If the first step gave rise to 1-D eigen-space of the density matrix, a state function reduction cascade at either upper of lower boundary of CD proceeding from long to short scales. At given step divides the sub-system into two systems and the sub-system-complement pair which produces maximum negentropy gain is subject to quantum measurement maximizing negentropy gain. The process stops at given subsystem resulting in the process if the resulting eigen-space is 1-D or has NE (p-adic prime p divides the dimension N of eigenspace in the intersection of reality and p-adicity).

3.2.4 Hyper-Finite Factors Of Type Ii_1 And Quantum Measurement Theory With A Finite Measurement Resolution

The realization that the von Neumann algebra known as hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition.

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of WCW . Also the local Clifford algebra of the embedding space $H = M^4 \times CP_2$ in octonionic representation of gamma matrices of H is important and the entire quantum TGD emerges from the associativity or co-associativity conditions for the sub-algebras of this algebra which are local algebras localized to maximal associative or co-associate sub-manifolds of the embedding space identifiable as space-time surfaces.

The notion of inclusion for hyper-finite factors provides an elegant description for the notion of measurement resolution absent from the standard quantum measurement theory.

1. The included sub-factor creates in zero energy ontology states not distinguishable from the original one and the formally the coset space of factors defining quantum spinor space defines the space of physical states modulo finite measurement resolution.

2. The quantum measurement theory for hyperfinite factors differs from that for factors of type I since it is not possible to localize the state into single ray of state space. Rather, the ray is replaced with the sub-space obtained by the action of the included algebra defining the measurement resolution. The role of complex numbers in standard quantum measurement theory is taken by the non-commutative included algebra so that a non-commutative quantum theory is the outcome.

3. This leads also to the notion of quantum group. For instance, the finite measurement resolution means that the components of spinor do not commute anymore and it is not possible to reduce the state to a precise eigenstate of spin. It is however perform a reduction to an eigenstate of an observable which corresponds to the probability for either spin state.

4. The realization for quantum measurement theory modulo finite measurement resolution is in terms of M-matrices defined in terms of Connes tensor product which essentially means that the included hyper-finite factor N takes the role of complex num bers.

As already explained, the topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a way that unentangled systems can possess entangled sub-systems. One can say that the entanglement between sub-selves is not visible in the resolution characterizing selves. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a deeper justification from the quantum measurement theory for hyper-finite factors of type II_1 for which the finite measurement resolution is basic notion.

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II_1 and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II_1 and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

3.2.5 NMP And Biology

The notion of self is crucial for the understanding of bio-systems and consciousness. It seems that the negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is the decisive element of life and that one can say that in metaphorical sense life resides in the intersection of real and p-adic worlds.

Generalization of the notion of information

TGD inspired theory of consciousness, in particular the formulation of Negentropy Maximization Principle (NMP) in p-adic context, has forced to rethink the notion of the information concept. In TGD state preparation process is realized as a sequence of self measurements and state preparation for next quantum jump is state reduction for the previous quantum jump. In zero energy ontology one can interpret the state preparation for positive and negative energy parts of the state as reduction and preparation in the sense of standard physics. Each self measurement means a decomposition of the sub-system involved to two unentangled parts unless the system is bound state. The decomposition is fixed highly uniquely from the requirement that the reduction of the entanglement entropy is maximal.

Bound state entanglement is stable against self measurement simply because energy conservation prevents the decay to a pair of free (uncorrelated) subsystems. The generalized definition of entanglement entropy allows to assign a negative value of entanglement entropy to rational and algebraic entanglement, so that this kind of entanglement would actually carry information, in fact conscious information (experience of understanding). This kind of entanglement cannot be reduced in state function reduction. Macro-temporal quantum coherence could correspond to a generation of either bound state entanglement or negentropic entanglement, and is indeed crucial for ability to have long lasting non-entropic mental images. Generation of negentropic entanglement would involve experience about expansion of consciousness and that of bound states entanglement a loss of consciousness.

The mathematical models for quantum computers typically operate with systems for which entanglement probabilities are identical. Also rational numbers are involved. Does this mean that negentropic entanglement makes possible quantum computation? This does not seem to be the case. State function reduction with random outcomes is a central element of quantum computation which suggests that quantum computation must be based on entropic entanglement with large enough value of $\hbar$ to overcome the restrictions caused by the interactions with the external world. The negentropic entanglement in turn would relate to conscious information processing involving experience of understanding represented by negentropic entanglement. Negentropic entanglement would make possible conscious cellular automaton type information processing much closer to that carried out by ordinary computers and this information processing might be equally important in living systems.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

NMP and negentropic entanglement demanding entanglement probabilities which are equal to inverse of integer, is the starting point. Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that in some sense life and conscious intelligence reside in the intersection of the real and p-adic worlds.

What could be this intersection of realities and p-adicities?

1. The facts that fermionic oscillator operators are correlates for Boolean cognition and that induced spinor fields are restricted to string world sheets and partonic 2-surfaces suggests that the intersection consists of these 2-surfaces.

2. Strong form of holography allows a rather elegant adelization of TGD by a construction of space-time surfaces by algebraic continuations of these 2-surfaces defined by parameters in algebraic extension of rationals inducing that for various p-adic number fields to real or p-adic number fields. Scattering amplitudes could be defined also by a similar algebraic contination. By conformal invariance the conformal moduli characterizing the 2-surfaces would defined the parameters.

This suggests a rather concrete view about the fundamental quantum correlates of life and intelligence.

1. For the minimal option life would be effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world

sheets partonic two-surfaces appears in U-matrix so that the data localizable to strings connecting partonic 2-surfaces would dictate the scattering amplitudes.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K3]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K83].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and also hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

That only algebraic extensions are possible is of course only a working hypothesis. Also finite-dimensional extensions of p-adic numbers involving transcendentals are possible and might in fact be necessary. Consider for instance the extension containing $e, e^2, .., e^{p-1}$ as units (e^p is ordinary p-adic number. Infinite number of analogous finite-dimensional extensions can be constructed by taking a function of integer variable such that $f(p)$ exists both p-adically and as a real transcendental number. The powers of $f(p)^{1/n}$ for a fixed value of n define a finite-dimensional transcendental extension of p-adic numbers if the roots do not exist p-adically.

Numbers like $log(p)$ and π cannot belong to a finite-dimensional extension of p-adic numbers [K42]. One cannot of course take any strong attitude concerning the possibility of infinite-dimensional extensions of p-adic numbers but the working hypothesis has been that they are absent. The phases $exp(i2\pi/n)$ define finite dimensional extensions allowing to replace the notion of angle in finite measurement resolution with the corresponding phase factors in finite measurement. The functions $exp(i2\pi q/n)$, where q is arbitrary p-adic integers define in a natural manner the physical counterparts of plane waves and angular momentum eigenstates not allowing an identification as ordinary p-adic exponential functions. They are clearly strictly periodic functions of q with a finite value set. If n is divisible by a power of p, these functions are continuous since the values of the function for q and $q + kp^n$ are identical for large enough values of n. This condition is essential and means in the case of plane waves that the size scale of a system (say one-dimensional box) is multiple of a power of p.

Evolution and second law

Evolution has many facets in TGD framework.

1. A natural characterization of evolution is in terms of p-adic topology relating naturally to cognition. p-Adic primes near powers of two are favored if CDs have the proposed discrete size spectrum. From the point of view of self this would be essentially cosmic expansion in discrete jumps. CDs and can be characterized by powers of 2 and if partonic 2-surfaces correspond to effective p-adic p-adic topology characterized by a power of two, one obtains the commeasurability of the secondary p-adic time scale of particle and that of CD in good approximation.

2. The notion of infinite primes motivates the hypothesis that the many-sheeted structure of space-time can be coded by infinite primes [K92]. The number of primes larger than given infinite prime P is infinitely larger than the number of primes than P. The infinite prime P characterizing the entire universe decomposes in a well defined manner to finite primes and p-adic evolution at the level of entire universe is implied by local p-adic evolution at the level of selves. Therefore maximum entanglement negentropy gain for p-adic self increases at least as $log(p)$ with p in the long run. This kind of relationship might hold true for real selves of p-adic physics is physics of cognitive representations of real physics as suggested by the success of p-adic mass calculations. Thus it should be possible to assign definite p-adic prime to each partonic 2-surface.

3. A further aspect of evolution relates to the hierarchy of Planck constants implying that at dark matter levels rational or at least integer multiples of the favored p-adic time scales are realized. The latter option is favored by the idea that the book like structure with pages consisting of many-sheeted coverings of CD and CP_2, and correlates with the emergence of algebraic extensions of p-adic numbers defined by the roots $exp(i2\pi/n)$ of unity. For the latter option evolution by quantum jumps would automatically imply the drifting of the partonic 2-surfaces to the pages of books labelled by increasing values of Planck constant. For more general option one might argue that drifting to pages with small values of Planck constant is also possible. This would give kind of antizooms of long length scale physics to short scales. Both kind of temporal zooms could be crucial for conscious intelligence building scaled models about time evolution in various scales.

4. The generation of negentropic entanglement between different number fields would of course be the fundamental aspect of evolution. It would give rise to increasingly complex and negentropic sensory perceptions and cognitive representations based on conscious rules coded by negentropic entanglement. This would justify the association concept as it used in neuro-science. Negentropic entanglement could be also crucial for the basic mechanism of metabolism and make possible conscious co-operation even in nano-scales.

Just for fun one can play also with numbers.

1. The highest dark matter level associated with self corresponds to its geometric duration which can be arbitrarily long: the typical duration of the memory span gives an idea about the level of dark matter hierarchy involved if one assumes that the time scale.1 seconds assignable to electrons is the fundamental time scale. If the time scale T of human life cycle corresponds to a secondary p-adic time scale then $T = 100$ years gives the rough estimate $r \equiv \hbar/\hbar_0 = 2^{33}$ if this time scale corresponds to that for dark electron. The corresponding primary p-adic time length scale corresponds to $k = 160$ and is 2.2×10^{-7} meters.

2. If human time scale -taken to be $T = 100$ years- corresponds to primary p-adic time scale of electron, one must have roughly $r = 2^{97}$.

I have already discussed the second law in TGD framework and it seems that its applies only when the time scale of perception is longer than the time scale characterizing the level of the p-adic and dark matter hierarchy. Second law as it is usually stated can be seen as an unavoidable implication of the materialistic ontology.

Stable entanglement and quantum metabolism as different sides of the same coin

The notion of binding has two meanings. Binding as a formation of bound state and binding as a fusion of mental images to larger ones essential for the functioning of brain and regarded as one the big problems of consciousness theory.

Only bound state entanglement and negentropic entanglement are stable against the state reduction process. Hence the fusion of the mental images implies the formation of a bound entropic state- in this case the two interpretations of binding are equivalent- or a negentropic state, which need not be bound state.

1. In the case of negentropic entanglement bound state need not be formed and the interesting possibility is that the negentropic entanglement could give rise to stable states without binding energy. This could allow to understand the mysterious high energy phosphate bond to which metabolic energy is assigned in ATP molecule containing three phosphates and liberated as ATP decays to ADP and phosphate molecule. Negentropic entanglement could also explain the stability of DNA and other highly charged biopolymers. In this framework the liberation of metabolic (negentropic) energy would involve dropping of electrons to a larger space-time sheets accompanying the process $ATP \rightarrow ADP + P_i$. A detailed model of this process is discussed in [K38, K39].

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

2. The formation of bound state entanglement is expected to involve a liberation of the binding energy and this energy might be a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and formation of bound states are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enhanced oxidative metabolism [J17] (that is $ATP \rightarrow ADP$ process and its reversal). A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

If these interpretations are correct, there would be two modes of metabolism corresponding to two different kinds of fusion of mental images.

3.2.6 Generalization Of Thermodynamics Allowing Negentropic Entanglement And A Model For Conscious Information Processing

The possibility of negetropic entanglement in TGD framework means that the second law of thermodynamics must be modified. The most obvious modification means only the replacement $S \rightarrow S - N$, where S is thermodynamical entropy and N the negentropy associated with negentropic entanglement. Hence the basic formulas of thermodynamics remain formally as such. The generalization leads to a thermodynamical model for how conscious information is generated and how metabolism relates to this. One can also understand why living matter is so effective entropy producer as compared to inanimate matter and the characteristic decomposition of living systems to highly negentropic and entropic parts.

A pessimistic modification of thermodynamics to take into account negentropic entanglement

What does the presence of the negentropic entanglement mean from the point of view of thermodynamics? There are two obvious options to consider. The optimistic option is just the standard thermodynamics saying nothing about negentropy generation. Indeed, number theoretic entanglement negentropy characterizes information carried by entanglement rather than ignorance about individual entangled state and is therefore not identifiable as thermodynamics entropy. The pessimistic option is that the generation of negentropy must be accompanied by a generation of at least the same amount of entropy: the good news is that this entropy can be carried by different system and it is possible to have genuinely negentropic systems.

The following consideration is restricted to the pessimistic option. Some-one might argue that this provides a more realistic view about the world we live in. One must however remember that evolution is an empirical fact as also dark matter about which we know practically nothing. Furthermore, I am unable to image a concrete mechanism guaranteeing that the generation of negentropic entanglement would be accompanied by a generation of ensemble entropy. The two negentropies are indeed different although there exists a connection. A large degeneracy of states to the geometric realization of $h_{eff} = nh$ hierarchy, implies a large thermodynamical entropy. It also makes possible negentropic entanglement with large number theoretical entanglement negentropy. Therefore large entropic resources implied degeneracy of states can be transformed to large negentropic resources by NMP. Dirt can be transformed to jewels (by love for which negentropic entanglement could serve as a quantum correlate!).

Second ZEO based prediction is that the arrow of thermodynamical time defined by the asymmetry between positive and negative energy parts of zero energy states alternates. There is evidence for this kind of alternation and this lead Fantappie to introduce the notion of syntropy long time ago [J20]. This aspect is not considered in the sequel.

1. One must generalize the basic expression for energy differential

$$dE = TdS - dW \rightarrow T(dS - dN) - dW \ . \tag{3.2.1}$$

   This means that there are two kinds of energies given out by the system. The useful work dW and negentropic energy TdN. For steam engine only dW is present. For ideal system only negentropic energy would be present.

2. What happens to the second law? The pessimistic guess is that generation of negentropy requires a generation of at least same amount of entropy so that one would have

$$\Delta S - \Delta N \geq 0 \ . \tag{3.2.2}$$

   Here S can be interpreted as a sum of two terms. The first part corresponds to the ensemble entropy generated by the randomness of ordinary quantum jumps, and second part to the entropy assignable as maximal entanglement entropy assignable to the decompositions of bound state to two parts. N corresponds to maximal negentropy for the decompositions of negentropic sub-system to pairs. One can criticize these definitions and a possible modification of could be as as the average for the entanglement entropies over this kind of decompositions.

3. Quite generally, Clausius inequality allowing to deduce extremization conditions for various thermodynamical potentials generalizes to

$$T_0(\Delta S - \Delta N) - \Delta E - P_0\Delta V \geq 0 \ . \tag{3.2.3}$$

   where T_0 and P_0 and temperature and pressure of heat bath. Living systems would be entropy producers and this seems to conform with what we see around us.

   For instance, for a system in constant volume one would have

$$\Delta S - \Delta N - \frac{\Delta E}{T} \geq 0 \ . \tag{3.2.4}$$

so that systems developing negentropy would also generate thermodynamics entropy. For a system in heat bath one has $T = T_0$ and Clausius inequality gives

$$\Delta F = -\Delta W \tag{3.2.5}$$

stating that increase of free energy at constant temperature requires work done on the system ($dW < 0$): otherwise $\Delta F \leq 0$ holds true.

By using the variable $S - N$ instead of S all formulas reduce formally to standard thermodynamics except that S can be negative.

The analog of Carnot cycle as a simple model for information processing in living matter

Carnot engine transforms heat to work. Costa de Beauregard [J8], [J8] has proposed a modification of Carnot engine as a model for information processing. One can consider Carnot engine and its information theoretic analog in this framework.

1. The basic equation for Carnot engine is

$$dW = dQ_{in} - dQ_{out} \geq 0 \ . \tag{3.2.6}$$

   Optimal efficiency corresponds to $dS_{out} = dS_{in}$.

2. The information theoretic analog of Carnot engine proposed by Beauregard does not perform work and one would have

$$dW = 0 \ , \tag{3.2.7}$$

   and

$$dN = dS_{out} - dS_{in} \geq 0 \ . \tag{3.2.8}$$

   The interpretation would be that incoming entropy flow leaves the computer in a state of higher entropy and the difference corresponds to information dN fed to say printer. The increase of entropy would have interpretation in terms of erasing of data from computer memory.

   The problematic aspect of the model is that it requires $T_{in} > T_{out}$ in order to have $dN > 0$. For living systems one has however typically $T_{in} < T_{out}$. Already for $T_{in} = T_{out}$ the situation trivializes since one has

$$dN = 0 \tag{3.2.9}$$

   by $dW = 0$ and $dS = dQ/T$.

3. In the recent case however a more general condition

$$T_{in}d(S_{in} - N_{in}) - T_{out}d(S_{out} - N_{out}) \quad \geq \quad 0 \tag{3.2.10}$$

holds true and allows to generate conscious information provided it is compensated by thermodynamical entropy. Note that the temperature of the environment can be even lower than the temperatures of the system.

It is also possible to transform information to work as the expression for the differential $dF = -SdT - TdN - dW$ of the generalized free energy $E = E - TS$ shows. The increase of dW for the work done by the system is compensated by the reduction of information dN so that system loses negentropy in the process keeping dF constant. The loss of negentropy couild be interpreted in terms of a loss of metabolic energy which corresponds to negentropic entanglement for AMP, ADP, and ATP molecules.

Basic biological implications

Some clarifying comments about biological implications are in order.

1. There is no need to restrict the consideration to equilibrium systems. First of all, the environment and living system are in general at different temperatures and temperature difference is typically of wrong sign for the model of Beauregard to work in this context. Beauregard's model is of course a model for computation, not for the generation of negentropic mental images. Maybe cognitive machine might be proper term for what the modified model could describe.

2. Quite generally, self-organization requires a feed of energy to the system so that one has flow equilibrium. In the case of living system this feed of energy is metabolic energy associated with the negentropic entanglement transferred to the system in the ATP-ADP process. Self-organization driven by negentropic entanglement leads to standardized negentropic mental images automatically as asymptotic self-organization patterns in 4-D sense (CDs within CDs within... : CD denotes causal diamond defined as cartesian produc to the intersection of the future and past directed light-cones with CP_2, which is the key notion in zero energy ontology).

3. No explicit assumptions about computational aspects of the process has been made. Just a generation of conscious information identified in terms of negentropic entanglement is assumed. The basic character quantum jump as U-process followed by the cascade of state function reductions represents a fractal hierarchy of what can be seen as quantum computations and are distinguished from classical computations in that the process proceeds from top to bottom rather than being a local process. The result of computation is represented using statistical ensembles defined by sub-CDs at various levels of the hierarchy and is in principle communicable by classical fields (say EEG patterns in the case of brain) to higher levels of self hierarchy which in turn can induces the same distributions so that communication of the objective aspects of the experience with the mediation of "medium" is possible. The presence of the "medium" seems unavoidable. Magnetic body would be this medium in TGD inspired biology.

Living matter involves also another aspect made possible by the generalized second law obtained by the replacement $S \rightarrow S - N$. Subsystem can have also negative net entropy and split to two highly negentropic and entropic pieces. In the extreme situation this is nothing but excretion, which is absolutely essential element of being alive but sometimes forgotten from the lists of properties distinguishing living matter from inanimate matter. It is not at all clear whether this is possible for standard non-equilibrium systems defining information as a reduction of disorder. At all levels of the fractal hierarchy division into negentropic and entropic subsystems is expected.

This picture seems to be in accordance with basic chemistry of energy metabolism.

1. The process creating both negentropy and entropy would be standardized in living matter and mean a generation of high energy phosphate bonds assignable to AMP, ADP, and ATP containing 1, 2, and 3 phosphates respectively besides the sugar residue. Sugar residue is basic nutrient and would provide the stored metabolic energy transformed to the negentropic energy of the high energy phosphate bonds if the proposed view is correct. Also other DNA nucleotides such as G can appear besides A but in metabolism A has a preferred role.

2. The basic metabolic cycle provides ADP with an additional phosphate energizing it to ATP and the reverse process transfers the metabolic energy and also negentropic entanglement to the acceptor molecule. Also ADP can provide metabolic energy by transforming to AMP when ATP is not available in sufficient amounts. That the catabolism of AMP creates urea excreted out of the system fits with the general picture. The catabolism for nutrients would create the entropy compensating for the negentropy of the high energy phosphate bonds.

3. The backbone of DNA is made of sugar and phosphate residues and corresponds to a sequence of XMP, $X = A, T, C, G$ with each XMP presumably containing single high energy phosphate bond serving as a storage or potential source of negentropy. This conforms with the view that DNA carries conscious information.

Negentropic and entropic entanglement are assumed to generate mental images with opposite emotional colors. This connects information processing with emotions. From neuroscience point of view this is not a news: peptides are molecules of emotions on one hand and molecules of information on the other hand [J6]. The well-known specialization of the left and right hand sides of the amygdala to experience positive and negatively colored emotions could be seen as one instance of this connection and representing also an example about fractal negentropic-entropic differentiation.

3.3 How Quantum Computation In TGD Universe Differs From Standard Quantum Computation?

Many problems of quantum computation in standard sense might relate to a wrong view about quantum theory. If TGD Universe is the physical universe, the situation would improve in many respects. There is the new fractal view about quantum jump and observer as "self" ; there is p-adic length scale hierarchy and hierarchy of Planck constants as well as self hierarchy; there is a new view about entanglement and the possibility of irreducible entanglement carrying genuine information and making possible quantum superposition of fractal quantum computations and quantum parallel dissipation; there is zero energy ontology, the notion of M-matrix allowing to understand quantum theory as a square root of thermodynamics, the notion of measurement resolution allowing to identify M-matrix in terms of Connes tensor product; there is also the notion of magnetic body providing one promising realization for braids in TQC, etc... This section gives a short summary of these aspects of TGD.

There is also a second motivation for this section. Quantum TGD and TGD inspired theory of consciousness involve quite a bundle of new ideas and the continual checking of internal consistency by writing it through again and again is of utmost importance. This section can be also seen as this kind of checking. I can only represent apologies to the benevolent reader: this is a work in rapid progress.

3.3.1 General Ideas Related To Topological Quantum Computation

Topological computation relies heavily on the representation of TQC program as a braiding. There are many kinds of braidings. Number theoretic braids are defined by the orbits of minima of vacuum expectation of Higgs at light-like partonic 3-surfaces (and also at space-like 3-surfaces). There are braidings defined by Kähler gauge potential (possibly equivalent with number theoretic ones) and by Kähler magnetic field. Magnetic flux tubes and partonic 2-surfaces interpreted as strands of define braidings whose strands are not infinitely thin. A very concrete and very complex time-like braiding is defined by the motions of people at the surface of globe: perhaps this sometimes purposeless-looking fuss has a deeper purpose: maybe those at the higher levels of dark matter hierarchy are using us to carry out complex topological quantum computations)!

General vision about quantum computation

In TGD Universe the hierarchy of Planck constants gives excellent prerequisites for all kinds of quantum computations. The general vision about quantum computation (TQC) would result as a special case and would look like follows.

1. Time-like entanglement between positive and negative energy parts of zero energy states would define the analogs of qc-programs. Space-like quantum entanglement between ends of strands whose motion defines time-like braids would provide a representation of q-information.

2. Both time- and space-like quantum entanglement would correspond to Connes tensor product expressing the finiteness of the measurement resolution between the states defined at ends of space-like braids whose orbits define time like braiding. The characterization of the measurement resolution would thus define both possible q-data and tq-programs as representations for "laws of physics".

3. The braiding between DNA strands with each nucleotide defining one strand transversal to DNA realized in terms of magnetic flux tubes was my first bet for the representation of space-like braiding in living matter. It turned out that the braiding is more naturally defined by flux tubes connecting nucleotides to the lipids of nuclear-, cell-, and endoplasma membranes. Also braidings between other microtubules and axonal membrane can be considered. The conjectured hierarchy of genomes giving rise to quantum coherent gene expressions in various scales would correspond to computational hierarchy.

About the relation between space-like and time-like number theoretic braidings

The relationship between space- and time-like braidings is interesting and there might be some connections also to 4-D topological gauge theories suggested by geometric Langlands program discussed in the previous posting and also in [K51].

1. The braidings along light-like surfaces modify space-like braiding if the moving ends of the space-like braids at partonic 3-surfaces define time-like braids. From TQC point of view the interpretation would be that TQC program is written to memory represented as the modification of space-like braiding in 1-1 correspondence with the time-like braiding.

2. The orbits of space-like braids define codimension two sub-manifolds of 4-D space-time surface and can become knotted. Presumably time-like braiding gives rise to a non-trivial "2-braid". Could also the "2-braiding" based on this knotting be of importance? Do 2-connections of n-category theorists emerge somehow as auxiliary tools? Could 2-knotting bring additional structure into the topological QFT defined by 1-braidings and Chern-Simons action?

3. The strands of dynamically evolving braids could in principle go through each other so that time evolution can transform braid to a new one also in this manner. This is especially clear from standard representation of knots by their planar projections. The points where intersection occurs correspond to self-intersection points of 2-surface as a sub-manifold of space-time surface. Topological QFT: s are also used to classify intersection numbers of 2-dimensional surfaces understood as homological equivalence classes. Now these intersection points would be associated with "braid cobordism".

Quantum computation as quantum superposition of classical computations?

It is often said that quantum computation is quantum super-position of classical computations. In standard path integral picture this does not make sense since between initial and final states represented by classical fields one has quantum superposition over *all* classical field configurations representing classical computations in very abstract sense. The metaphor is as good as the perturbation theory around the minimum of the classical action is as an approximation.

In TGD framework the classical space-time surface is a preferred extremal of Kähler action so that apart from effects caused by the failure of complete determinism, the metaphor makes sense precisely. Besides this there is of course the computation associated with the spin like degrees of freedom in which one has entanglement and which one cannot describe in this manner.

For TQC a particular classical computation would reduce to the time evolution of braids and would be coded by 2-knot. Classical computation would be coded to the manipulation of the braid. Note that the branching of strands of generalized number theoretical braids has interpretation as classical communication.

The identification of topological quantum states

Quantum states of TQC should correspond to topologically robust degrees of freedom separating neatly from non-topological ones.

1. The generalization of the embedding space inspired by the hierarchy of Planck constants suggests an identification of this kind of states as elements of the group algebra of discrete subgroup of $SO(3)$ associated with the group defining covering of M^4 or CP_2 or both in large $\hbar$ sector. One would have wave functions in the discrete space defined by the homotopy group of the covering transforming according to the representations of the group. This is by definition something robust and separated from non-topological degrees of freedom (standard model quantum numbers). There would be also a direct connection with anyons.

2. An especially interesting group is dodecahedral group corresponding to the minimal quantum phase $q = exp(2\pi/5)$ (Golden Mean) allowing a universal topological quantum computation: this group corresponds to Dynkin diagram for E_8 by the ALE correspondence. Interestingly, neuronal synapses involve clathrin molecules [I10] associated with microtubule ends possessing dodecahedral symmetry.

Some questions

A conjecture inspired by the inclusions of HFFs is that these states can be also regarded as representations of various gauge groups which TGD dynamics is conjectured to be able to mimic so that one might have connection with non-Abelian Chern-Simons theories where topological S-matrix is constructed in terms of path integral over connections: these connections would be only an auxiliary tool in TGD framework.

1. Do these additional degrees of freedom give only rise to topological variants of gauge- and conformal field theories? Note that if the earlier conjecture that entire dynamics of these theories could be mimicked, it would be best to perform TQC at quantum criticality where either M^4 or CP_2 dynamical degrees of freedom or both disappear.

2. Could it be advantageous to perform TQC near quantum criticality? For instance, could one construct magnetic braidings in the visible sector near q-criticality using existing technology and then induce phase transition changing Planck constant by varying some parameter, say temperature.

3.3.2 Fractal Hierarchies

Fractal hierarchies are the essence of TGD. There is hierarchy of space-time sheets labelled by preferred p-adic primes. There is hierarchy of Planck constants reflecting a book like structure of the generalized embedding space and identified in terms of a hierarchy of dark matters. These hierarchies correspond at the level of conscious experience to a hierarchy of conscious entities - selves: self experiences its sub-selves as mental images.

Fractal hierarchies mean completely new element in the model for quantum computation. The decomposition of quantum computation to a fractal hierarchy of quantum computations is one implication of this hierarchy and means that each quantum computation proceeds from longer to shorter time scales $T_n = T_0 2^{-n}$ as a cascade like process such that at each level there is a large number of quantum computations performed with various values of input parameters defined by the output at previous level. Under some additional assumptions to be discussed later this hierarchy involves at a given level a large number of replicas of a given sub-module of TQC so that the output of single fractal sub-module gives automatically probabilities for various outcomes as required.

3.3.3 Irreducible Entanglement And Possibility Of Quantum Parallel Quantum Computation

The basic distinction from standard measurement theory is irreducible entanglement not reduced in quantum jump. There are two kinds of irreducible entanglement: both are negentropic. First kind of irreducible entanglement corresponds to a density matrix, which is proportional to $n \times n$ unit matrix and is naturally associated with the $h_{eff} = nh$ hierarchy. If the entanglement matrix is unitary, density matrix is proportional to unit matrix. One can consider various restrictions on the unitary matrix and these were already discussed. The assumption that the unitary matrix is representable as TQC with basic gate defined by braiding operation is very natural and gives connection between consciousness and quantum computation.

One can imagine also a second candidate for irreducible entanglement. If the density matrix belongs to an algebraic extension of p-adic numbers, one can assign to it number theoretic negentropy. The diagonalized density matrix can however belong to a higher-dimensional algebraic extension than the matrix elements of the entanglement matrix itself. Does this mean that state function reduction can take place only if it is accompanied by an evolutionary step increasing the dimension of algebraic extension involved?

NMP and the possibility of irreducible entanglement

Negentropy Maximimization Principle (NMP) states that entanglement entropy is minimized in quantum jump. For standard Shannon entropy this would lead to a final state which corresponds to a ray of state space. If entanglement probabilities are rational - or even algebraic - one can replace Shannon entropy with its number theoretic counterpart in which p-adic norm of probability replaces the probability in the argument of logarithm: $log(p_n) \rightarrow log(|p_n|_p)$. This entropy can have negative values. It is not quite clear whether prime p should be chosen to maximize the number theoretic negentropy or whether p is the p-adic prime characterizing the light-like partonic 3-surface in question.

Obviously NMP favors generation of irreducible entanglement which however can be reduced in U process. Irreducible entanglement is something completely new and the proposed interpretation is in terms of experience of various kinds of conscious experiences with positive content such as understanding.

Quantum superposition of unitarily evolving quantum states generalizes to a quantum superposition of quantum jump sequences defining dissipative time evolutions. Dissipating quarks inside quantum coherent hadrons would provide a basic example of this kind of situation.

Quantum parallel quantum computations and conscious experience

The combination of quantum parallel quantum jump sequences with the fractal hierarchies of scales implies the possibility of quantum parallel quantum computations. In ordinary quantum computation halting selects single computation but in the recent case arbitrarily large number of computations can be carried out simultaneously at various branches of entangled state. The probability distribution for the outcomes is obtained using only single computation.

One would have quantum superposition of space-time sheets (assignable to the maxima of Kähler function) each representing classically the outcome of a particular computation. Each branch would correspond to its own conscious experience but the entire system would correspond to a self experiencing consciously the outcome of computation as intuitive and holistic understanding, and abstraction. Emotions and emotional intellect could correspond to this kind of non-symbolic representation for the outcome of computation as analogs for collective parameters like temperature and pressure.

Delicacies

There are several delicacies involved.

1. The above argument works for factors of type I. For HFFs of type II_1 the finite measurement resolution characterized in terms of the inclusion $\mathcal{N} \subset \mathcal{M}$ mean is that state function reduction takes place to $\mathcal{N}$-ray. There are good reasons to expect that the notion of number theoretic entanglement negentropy generalizes also to this case. Note that the entanglement associated with $\mathcal{N}$ is below measurement resolution.

2. In TGD inspired theory of consciousness irreducible entanglement makes possible sharing and fusion of mental images. At space-time level the space-time sheets corresponding to selves are disjoint but the space-time sheets topologically condensed at them are joined typically by what I call flux tubes identifiable as braid strands (magnetic flux quanta). In topological computation with finite measurement resolution this kind of entanglement with environment would be below the natural resolution and would not be a problem.

3. State function reduction means quantum jump to an eigen state of density matrix. Suppose that density matrix has rational elements. Number theoretic vision forces to ask whether the quantum jump to eigen state is possible if the eigenvalues of ρ do not belong to the algebraic extension of rationals and p-adic numbers used. If not, then one would have number theoretically irreducible entanglement depending on the algebraic extension used. If the eigenvalues actually define the extension there would be no restrictions: this option is definitely simpler.

4. Fuzzy quantum logic [K110] brings also complications. What happens in the case of quantum spinors that spin ceases to be observable and one cannot reduce the state to spin up or spin down. Rather, one can measure only the eigenvalues for the probability operator for spin up (and thus for spin down) so that one has fuzzy quantum logic characterized by quantum phase. Inclusions of HFFs are characterized by quantum phases and a possible interpretation is that the quantum parallelism related to the finite measurement resolution could give rise to fuzzy qubits. Also the number theoretic quantum parallelism implied by number theoretic NMP could effectively make probabilities as operators. The probabilities for various outcomes would correspond to outcomes of quantum parallel state function reductions.

3.3.4 Possible Problems Related To Quantum Computation

At least following problems are encountered in quantum computation.

1. How to preserve quantum coherence for a long enough time so that unitary evolution can be achieved?

2. The outcome of calculation is always probability distribution: for instance, the output with maximum probability can correspond to the result of computation. The problem is how to replicate the computation to achieve the desired accuracy. Or more precisely, how to produce replicas of the hardware of quantum computer defined in terms of classical physics?

3. How to isolate the quantum computer from the external world during computation and despite this feed in the inputs and extract the outputs?

The notion of coherence region in TGD framework

In standard framework one can speak about coherence in two senses. At the level of Schrödinger amplitudes one speaks about coherence region inside which it makes sense to speak about Schrödinger time evolution. This notion is rather defined.

In TGD framework coherence region is identifiable as a region inside which the Kähler-Dirac equation holds true. Strictly speaking, this region corresponds to a light-like partonic 3-surface whereas 4-D space-time sheet corresponds to coherence region for classical fields. p-Adic length scale hierarchy and hierarchy of Planck constants means that arbitrarily large coherence regions are possible.

The precise definition for the notion of coherence region and the presence of scale hierarchies imply that the coherence in the case of single quantum computation is not a problem in TGD framework. De-coherence time or coherence time correspond to the temporal span of space-time sheet and a hierarchy coming in powers of two for a given value of Planck constant is predicted by basic quantum TGD. p-Adic length scale hypothesis and favored values of Planck constant would naturally reflect this fundamental fractal hierarchy.

De-coherence of density matrix and replicas of TQC

Second phenomenological description boils down to the assumption that non-diagonal elements of the density matrix in some preferred basis (involving spatial localization of particles) approach to zero. The existence of more or less faithful replicas of space-time sheet in given scale allows to identify the counterpart of this notion in TGD context. De-coherence would mean a loss of information in the averaging of M-matrix and density matrix associated with these space-time sheets.

Topological computations are probabilistic. This means that one has a collection of space-time sheets such that each space-time sheet corresponds to more or less the same TQC and therefore the same M-matrix. If M is too random (in the limits allowed by Connes tensor product), the analog of generalized phase information represented by its "phase" - S-matrix - is useless.

In order to avoid de-coherence in this sense, the space-time sheets must be approximate copies of each other. Almost copies are expected to result by dissipation leading to asymptotic self-organization patterns depending only weakly on initial conditions and having also space-time correlates. Obviously, the role of dissipation in eliminating effects of de-coherence in TQC would be something new. The enormous symmetries of M-matrix, the uniqueness of S-matrix for given resolution and parameters characterizing braiding, fractality, and generalized Bohr orbit property of space-time sheets, plus dissipation give good hopes that almost replicas can be obtained.

Isolation and representations of the outcome of TQC

The interaction with environment makes quantum computation difficult. In the case of topological quantum computation this interaction corresponds to the formation of braid strands connecting the computing space-time sheet with space-time sheets in environment. The environment is four-dimensional in TGD framework and an isolation in time direction might be required. The space-time sheets responsible for replicas of TQC should not be connected by light-like braids strands having time-like projections in M^4.

Length scale hierarchy coming in powers of two and finite measurement resolution might help considerably. Finite measurement resolution means that those strands which connect space-time sheets topologically condensed to the space-time sheets in question do not induce entanglement visible at this level and should not affect TQC in the resolution used.

Hence only the elimination of strands responsible for TQC at given level and connecting computing space-time sheet to space-time sheets at same level in environment is necessary and would require magnetic isolation. Note that super-conductivity might provide this kind of isolation. This kind of elimination could involve the same mechanism as the initiation of TQC which cuts the braid strands so the initiation and isolation might be more or less the same thing.

Strands reconnect after the halting of TQC and would make possible the communication of the outcome of computation along strands by using say em currents in turn generating generalized EEG, nerve pulse patterns, gene expression, etc... halting and initiation could be more or less synonymous with isolation and communication of the outcome of TQC.

How to express the outcome of quantum computation?

The outcome of quantum computation is basically a representation of probabilities for the outcome of TQC. There are two representations for the outcome of TQC. Symbolic representation which quite generally is in terms of probability distributions represented in terms "classical space-time" physics. The rates for various processes having basically interpretation as geometro-temporal densities would represent the probabilities just as in the case of particle physics experiment. For TQC in living matter this would correspond to gene expression, neural firing, EEG patterns, ...

A representation as a conscious experience is another (and actually the ultimate) representation of the outcome. It need not have any symbolic counterpart since it is felt. Intuition, emotions and emotional intelligence would naturally relate to this kind of representation made possible by irreducible entanglement. This representation would be based on fuzzy qubits and would mean that the outcome would be true or false only with certain probability. This unreliability would be felt consciously.

The proposed model of TQC combined with basic facts about theta waves [J23, J27] to be discussed in the subsection about the role of supra currents in TQC suggests that EEG rhythm (say theta rhythm) and correlated firing patterns correspond to the isolation at the first half period of TQC and random firing at second half period to the sub-sequent TQC: s at shorter time scales coming as negative powers of 2. The fractal hierarchy of time scales would correspond to a hierarchy of frequency scales for generalized EEG and power spectra at these scales would give information about the outcome of TQC. Synchronization would be obviously an essential element in this picture and could be understood in terms of classical dynamics which defines space-time surface as a generalized Bohr orbit.

Tqc would be analogous to the generation of a dynamical hologram or "conscious hologram" [K19]. EEG rhythm would correspond to reference wave generated by magnetic body as control and coordination signal and the contributions of spikes to EEG generated by neurons would correspond to the incoming wave interfering with the reference wave.

How data is fed into submodules of TQC?

Scale hierarchy obviously gives TQC a fractal modular structure and the question is how data is fed to submodules at shorter length scales. There are certainly interactions between different levels of scale hierarchy. The general ideas about master-slave hierarchy assigned with self-organization support the hypothesis that these interactions are directed from longer to shorter scales and have interpretation as a specialization of input data to TQC sub-modules represented by smaller space-time sheets of hierarchy. The call of submodule would occur when the TQC of the calling module halts and the result of computation is expressed as a 4-D pattern. The lower level module would start only after the halting of TQC (with respect to subjective time at least) and the durations of resulting TQC's would come as $T_n = 2^{-n}T_0$ that geometric series of TQC's would become possible. There would be entire family of TQC's at lower level corresponding to different values of input parameters from calling module.

One of the ideas assigned to hyper-computation [B1] is that one can have infinite series of computations with durations comings as negative powers of 2 (Zeno paradox obviously inspires this idea). In TGD framework there can be however only a finite series of these TQC's since CP_2 time scale poses a lower bound for the duration of TQC. One might of course ask whether the spectrum of Planck constant could help in this respect.

The role of dissipation and energy feed

Dissipation plays key role in the theory of self-organizing systems [B3]. Its role is to serve as a Darwinian selector. Without an external energy feed the outcome is a situation in which all organized motions disappear. In presence of energy feed highly unique self-organization patterns depending only very weakly on the initial conditions emerge.

In the case of TQC one function of dissipation would be to drive the braidings to static standard configurations, and perhaps even effectively eliminate fluctuations in non-topological degrees of freedom. Note that magnetic fields are important for 1-gates. Magnetic flux conservation however saves magnetic fields from dissipation.

External energy feed is needed in order to generate new braidings. For the proposed model of cellular TQC the flow of intracellular water induces the braiding and requires energy feed. Also now dissipation would drive this flow to standard patterns coding for TQC programs. Metabolic energy would be also needed in order to control whether lipids can flow or not by generating cis type unsaturated bonds. Obviously, energy flows defining self organization patterns would define TQC programs.

Is it possible to realize arbitrary TQC?

The 4-D spin glass degeneracy of TGD Universe due to the enormous vacuum degeneracy of Kähler action gives good hopes that the classical dynamics for braidings allows to realize every possible TQC program. As a consequence, space-time sheets decompose to maximal non-deterministic regions representing basic modules of TQC. Similar decomposition takes place at the level of light-like partonic 3-surfaces and means decomposition to 3-D regions inside which conformal invariance eliminates light-like direction as dynamical degree of freedom so that the dynamics is effectively that of 2-dimensional object. Since these 3-D regions behave as independent units as far as longitudinal conformal invariance is considered, one can say that light-like 3-surfaces are 3-dimensional in discretized sense. In fact, for 2-D regions standard conformal invariance implies similar effective reduction to 1-dimensional dynamics realized in terms of a net of strings and means that 2-dimensionality is realized only in discretized sense.

3.3.5 Negentropic Entanglement, NMP, Braiding And TQC

Negentropic entanglement, NMP, braiding and TQC

Negentropic entanglement for which number theoretic entropy characterized by p-adic prime is negative so that entanglement carries information, is in key role in TGD inspired theory of consciousness and quantum biology.

1. The key feature of 2-particle negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is that density matrix is projector and thus proportional to unit matrix so that the assumption that state function reduction corresponds to the measurement of density matrix does not imply state function reduction to one-dimensional sub-space. This special kind of degenerate density matrix emerges naturally for the hierarchy $h_{eff} = n \times h$ interpreted in terms of a hierarchy of dark matter phases. I have already earlier considered explicit realizations of negentropic entanglement assuming that E is invariant under the group of unitary or orthogonal transformations (also subgroups of unitary group can be considered -say symplectic group). One can however consider much more general options and this leads to a connection with topological quantum computation (TQC).

2. Entanglement matrix E equal to $1/\sqrt{n}$ factor times unitary matrix U (as a special case orthogonal matrix O) defines a density matrix given by $\rho = UU^\dagger/n = Id_n/n$, which is group invariant. One has NE respected by state function reduction if NMP is assumed. This would give huge number of negentropically entangled states providing a representation for some unitary group or its subgroup (such as symplectic group). In principle any unitary representation of any Lie group would allow representation in terms of NE. In principle any unitary representation of any Lie group would allow a representation in terms of NE.

3. In physics as generalized number theory vision, a natural condition is that the matrix elements of E belong to the algebraic extension of p-adic numbers used so that discreted algebraic subgroups of unitary or orthogonal group are selected. This realizes evolutionary hierarchy as a hierarchy of p-adic number fields and their algebraic extensions, and one can imagine that evolution of cognition proceeds by the generation of negentropically entangled systems with increasing algebraic dimensions and increasing dimension reflecting itself as an increase of the largest prime power dividing n and defining the p-adic prime in question.

4. One fascinating implication is the ability of TGD Universe to emulate itself like Turing machine: unitary S-matrix codes for scattering amplitudes and therefore for physics and negentropically entangled subsystem could represent sub-matrix for S-matrix as rules representing “the laws of physics” in the approximation that the world corresponds to n-dimension Hilbert space. Also the limit $n \to \infty$ makes sense, especially so in the p-adic context where real infinity can correspond to finite number in the sense of p-adic norm. Here also dimensions n given as products of powers of infinite primes can be formally considered.

One can consider various restrictions on E.

1. In 2-particle case the stronger condition that E is group invariant implies that unitary matrix is identity matrix apart from an overall phase factor: $U = exp(i\phi)Id$. In orthogonal case the phase factor is ± 1. For n-particle NE one can consider group invariant states by using n-dimensional permutation tensor $\epsilon_{i_1,\ldots i_n}$.

2. One can give up the group invariance of E and consider only the weaker condition that permutation is represented as transposition of entanglement matrix: $C_{ij} \to C_{ij}$. Symmetry/antisymmetry under particle exchange would correspond to $C_{ji} = \epsilon C_{ij}$, $\epsilon = \pm 1$. This would give in orthogonal case $OO^T = O^2 = Id$ and $UU^* = Id$ in unitary case.

   In the unitary case particle exchange could be identified as hermitian conjugation $C_{ij} \to C^*_{ji}$ and one would have $U^2 = Id$. Euclidian gamma matrices γ_i define unitary and hermitian generators of Clifford algebra having dimension 2^{2m} for $n = 2m$ and $n = 2m + 1$. It is relatively easy to verify that the squares of completely anti-symmetrized products of k gamma matrices representing exterior algebra normalized by factor $1/\sqrt{k!}$ are equal to unit matrix. For $k = n$ the anti-symmetrized product gives essentially permutation symbol times the product $\prod_k \gamma_k$. In this manner one can construct entanglement matrices representing negentropic bi-partite entanglement.

3. The possibility of taking tensor products $\epsilon_{ij..k...n}\gamma_i \otimes \gamma_j .. \otimes \gamma_k$ of k gamma matrices means that one can has also co-product of gamma matrices. What is interesting is that quantum groups important in topological quantum computation as well as the Yangian algebra associated with twistor Grassmann approach to scattering amplitudes possess co-algebra structure. TGD leads also to the proposal that this structure plays a central role in the construction of scattering amplitudes. Physically the co-product is time reversal of product representing fusion of particles.

4. One can go even further. In 2-dimensional QFTs braid statistics replaces ordinary statistics. The natural question is what braid statistics could correspond to at the level of NE. Braiding matrix is unitary so that it defines NE. Braiding as a flow replaces the particle exchange and lifts permutation group to braid group serving as its infinite covering.

   The allowed unitary matrices representing braiding in tensor product are constructed using braiding matrix R representing the exchange for two braid strands? The well-known Yang-Baxter equation for R defined in tensor product as an invertible element (`http://tinyurl.com/yax3j6mr`) expresses the associativity of braiding operation. Concretely it states that the two braidings leading from 123 to 321 produce the same result. Entanglement matrices constructed R as basic operation would correspond to unitary matrices providing a representation for braids and each braid would give rise to one particular NE.

   This would give a direct connection with TQC for which the entanglement matrix defines a density matrix proportional to $n \times n$ unit matrix: R defines the basic gate [B36]. Braids would provide a concrete space-time correlate for NE giving rise to "Akashic records". Note that in string theory-GRT framework this old idea of TGD has been recently introduced by Maldacena and Sussking as a proposal that wormholes connecting blackholes provide a description of entanglement.

   I have indeed proposed the interpretation of braidings as fundamental memory representations much before the vision about Akashic records. This kind of entanglement matrix need not represent only time-like entanglement but can be also associated also with space-like entanglement. The connection with braiding matrices supports the view that magnetic flux tubes are carriers of negentropically entangled matter and also suggests that this kind of entanglement between -say- DNA and nuclear or cell membrane gives rise to TQC.

Some comments concerning the covering space degrees of freedom associated with $h_{eff} = n \times h$ viz. ordinary degrees of freedom are in order.

1. Negentropic entanglement with n entangled states would correspond naturally to $h_{eff} = n \times h$ and is assigned with "many-particle" states, which can be localized to the sheets of covering but one cannot exclude similar entanglement in other degrees of freedom. Group invariance leaves only group singlets and states which are not singlets are allowed only in special cases. For instance for $SU(2)$ the state $|j,m\rangle = |1,0\rangle$ represented as 2-particle state of 2 spin 1/2 particles is negentropically entangled whereas the states $|j,m\rangle = |1,\pm 1\rangle$ are pure.

2. Negentropic entanglement associated with $h_{eff} = n \times h$ could factorize as tensor product from other degrees of freedom. Negentropic entanglement would be localised to the covering

space degrees of freedom but there would be entropic entanglement in the ordinary degrees of freedom - say spin. The large value of h_{eff} would however scale up the quantum coherence time and length also in the ordinary degrees of freedom. For entanglement matrix this would correspond to a direct sum proportional to unitary matrices so that also density matrix would be a direct sum of matrices $p_nE_n = p_nId_n/n$, $\sum p_n = 1$ correspond ing to various values of "other quantum numbers", and state function reduction could take place to any subspace in the decomposition. Also more general entanglement matrices for which the dimensions of direct summands vary, are possible.

3. One can argue that NMP in form does not allow halting of quantum computation. This is not true. The computation halts but in different manner since negentropic entanglement tends to be generated even for weak form of NMP. Weak form of NMP allows also ordinary state function reduction. State function reduction is not need if NE can be directly experienced and self represents this mental image as a kind of abstraction or rule with the state pairs in the superposition representing the instances of the rule.

   It might be also possible to deduce the structure of negentropically entangled state by an interaction free quantum measurement replacing the state function reduction with "externalised" state function reduction. One could speak of interaction free TQC. This TQC would be reading of "Akashic records".

4. One could also counter argue that NMP allows the transfer of NE from the system so that TQC halts. NMP allows this if some another system receives at least the negentropy contained by NE. The interpretation would be as the increase of information obtained by a conscious observer about the outcome of halted quantum computation.

   Metabolism could quite concretely correspond the transfer of NE associated with the NE between nutrient molecules and some system. This would satisfy the demands of NMP and make possible for the organism to avoid the first state function reduction to the opposite boundary of CD (death) In [K71] it is suggested that this system can be of astrophysical size, say gravitational Mother Gaia with magnetic flux tubes characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0 = \hbar_{eff} = n \times \hbar$, where v_0 is a parameter with dimensions of velocity. There is experimental evidence for dark matter shell around Earth [K88] and there are highly interesting connection to the hypothesis identifying bio-photons as decay products of dark photons located at magnetic flux tubes and having $h_{eff} = h_{gr}$.

3.4 DNA As Topological Quantum Computer

Braids [A1] code for topological quantum computation. One can imagine many possible identifications of braids but this is not essential for what follows. What is highly non-trivial is that the motion of the ends of strands defines both time-like and space-like braidings with latter defining in a well-defined sense a written version of the TQC program, kind of log file. The manipulation of braids is a central element of TQC and if DNA really performs TQC, the biological unit modifying braidings should be easy to identify. An obvious signature is the 2-dimensional character of this unit.

3.4.1 Conjugate DNA As Performer Of TQC And Lipids As Quantum Dancers

In this section the considerations are restricted to DNA as TQC. It is however quite possible that also RNA and other biomolecules could be involved with TQC like process.

Sharing of labor

The braid strands must begin from DNA double strands. Precisely which part of DNA does perform TQC? Genes? Introns [I22] ? Or could it be conjugate DNA which performs TQC? The function of conjugate DNA has indeed remained a mystery and sharing of labor suggests itself.

Conjugate DNA would do TQC and DNA would "print" the outcome of TQC in terms of RNA yielding amino-acids in the case of exons. RNA could the outcome in the case of introns.

The experience about computers and the general vision provided by TGD suggests that introns could express the outcome of TQC also electromagnetically in terms of standardized field patterns. Also speech would be a form of gene expression. The quantum states braid would entangle with characteristic gene expressions. This hypothesis will be taken as starting point in the following considerations.

Cell membranes as modifiers of braidings defining TQC programs?

The manipulation of braid strands transversal to DNA must take place at 2-D surface. The ends of the space-like braid are dancers whose dancing pattern defines the time-like braid, the running of classical TQC program. Space-like braid represents memory storage and TQC program is automatically written to memory during the TQC. The inner membrane of the nuclear envelope and cell membrane with entire endoplasmic reticulum included are good candidates for dancing hall. The 2-surfaces containing the ends of the hydrophobic ends of lipids could be the parquets and lipids the dancers. This picture seems to make sense.

1. Consider first the anatomy of membranes. Cell membrane [I4] and membranes of nuclear envelope [I34] consist of 2 lipid [I25] layers whose hydrophobic ends point towards interior. There is no water here nor any direct perturbations from the environment or interior milieu of cell. Nuclear envelope consists of two membranes having between them an empty volume of thickness 20-40 nm. The inner membrane consists of two lipid layers like ordinary cell membrane and outer membrane is connected continuously to endoplasmic reticulum [I13], which forms a highly folded cell membrane. Many biologists believe that cell nucleus is a prokaryote, which began to live in symbiosis with a prokaryote defining the cell membrane.

2. What makes dancing possible is that the phospholipid layers of the cell membrane are liquid crystals [D2]: the lipids can move freely in the horizontal direction but not vertically. "Phospho" could relate closely to the metabolic energy needs of dancers. If these lipids are self-organized around braid strands, their dancing patterns along the membrane surface would be an ideal manner to modify braidings since the lipids would have standard positions in a lattice. This would be like dancing on a chessboard. Note that the internal structure of lipid does not matter in this picture since it is braid color dicated by DNA nucleotide which matters. As a matter fact, living matter is full of self-organizing liquid crystals and one can wonder whether the deeper purpose of their life be running and simultaneous documentation of TQC programs?

3. Ordinary computers have an operating system: a collection of standard programs - the system - and similar situation should prevail now. The "printing" of outputs of TQC would represent example of this kind of standard program. This TQC program should not receive any input from the environment of the nucleus and should therefore correspond to braid strands connecting conjugate strand with strand. Braid strands would go only through the inner nuclear membrane and return back and would not be affected much since the volume between inner and outer nuclear membranes is empty. This assumption looks ad hoc but it will be found that the requirement that these programs are inherited as such in the cell replication necessitates this kind of structure (see the section "Cell replication and TQC").

4. The braid strands starting from the conjugate DNA could traverse several time through the highly folded endoplasmic reticulum but without leaving cell interior and return back to nucleus and modify TQC by intracellular input. Braid strands could also traverse the cell membrane and thus receive information about the exterior of cell. Both of these TQC programs could be present also in prokaryotes [I41] but the braid strands would always return back to the DNA, which can be also in another cell. In multicellulars (eukaryotes [I15]) braid strands could continue to another cell and give rise to "social" TQC programs performed by the multicellular organisms. Note that the topological character of braiding does not require isolation of braiding from environment. It might be however advantageous to have some kind of sensory receptors amplifying sensory input to standardized re-braiding patterns. Various receptors in cell membrane would serve this purpose.

5. Braid strands can end up at the parquet defined by ends of the inner phospholipid layer: their distance of inner and outer parquet is few nanometers. They could also extend further.

   (a) If one is interested in connecting cell nucleus to the membrane of another cell, the simpler option is the formation of hole defined by a protein attached to cell membrane. In this case only the environment of the second cell affects the braiding assignable to the first cell nucleus.

   (b) The bi-layered structure of the cell membrane could be essential for the build-up of more complex TQC programs since the strands arriving at two nearby hydrophobic 2-surfaces could combine to form longer strands. The formation of longer strands could mean the fusion of the two nearby hydrophobic two-surfaces in the region considered.

      i. The original naïve idea was that TQC could begin with the cutting of the strands so that non-trivial braiding could be generated via lipid dance and TQC would halt when strands would recombine and define a modified braiding. There are however strong objections about cutting since boundaries are not favored by boundary connections.

      ii. If there is a U-shaped flux tube from interior to the exterior and returning back, reconnection at cell membrane could create two U-shaped loops inside and outside the cell membrane. The U-shaped loop could also correspond make the turn through wormhole contact so that the effective splitting would create two wormhole contacts. The latter option fixes completely DNA TQC option based on quarks and antiquarks. If Cooper pairs of charged spin 1/2 fermions forming four spin states assumed to correspond A, T, C, G the first option is the natural one.

   This would allow to connect cell nucleus and cell membrane to a larger TQC unit and cells to multicellular TQC units so that the modification of TQC programs by feeding the information from the exteriors of cells - essential for the survival of multicellulars - would become possible.

Gene expression and other basic genetic functions from TQC point of view

It is useful to try to imagine how gene expression might relate to the halting of TQC. There are of course myriads of alternatives for detailed realizations, and one can only play with thoughts to build a reasonable guess about what might happen.

1. Qubits for transcription factors and other regulators

Genetics is consistent with the hypothesis that genes correspond to those TQC moduli whose outputs determine whether genes are expressed or not. The naïve first guess would be that the value of single qubit determines whether the gene *is* expressed or not. Next guess replaces "*is* " with "*can be* ".

Indeed, gene expression involves promoters, enhancers and silencers [I42]. Promoters are portions of the genome near genes and recognized by proteins known as transcription factors [I48]. Transcription factors bind to the promoter and recruit RNA polymerase, an enzyme that synthesizes RNA. In prokaryotes RNA polymerase itself acts as the transcription factor. For eukaryotes situation is more complex: at least seven transcription factors are involved with the recruitment of the RNA polymerase II catalyzing the transcription of the messenger RNA. There are also transcription factors for transcription factors and transcription factor for the transcription factor itself.

The implication is that several qubits must have value "Yes" for the actual expression to occur since several transcription factors are involved with the expression of the gene in general. In the simplest situation this would mean that the computation halts to a measurement of single qubit for subset of genes including at least those coding for transcription factors and other regulators of gene expression.

2. Intron-exon qubit

Genes would have very many final states since each nucleotide is expected to correspond to at least single qubit. Without further measurements that state of nucleotides would remain highly entangled for each gene. Also these other qubits are expected to become increasingly important during evolution.

For instance, eukaryotic gene expression involves a transcription of RNA and splicing out of pieces of RNA which are not translated to amino-acids (introns). Also the notion of gene is known to become increasingly dynamical during the evolution of eukaryotes so that the expressive power of genome increases. A single qubit associated with each codon telling whether it is spliced out or not would allow maximal flexibility. Tqc would define what genes are and the expressive power of genes would be due to the evolution of TQC programs: very much like in the case of ordinary computers. Stopping sign codon and starting codon would automatically tell where the gene begins and ends if the corresponding qubit is "Yes". In this picture the old fashioned static genes of prokaryotes without splicings would correspond to TQC programs for which the portions of genome with a given value of splicing qubit are connected.

3. What about braids between DNA, RNA, tRNA and amino-acids

This simplified picture might have created the impression that amino-acids are quantum outsiders obeying classical bio-chemistry. For instance, transcription factors would in this picture end up to the promoter by a random process and "Print" would only increase the density of the transcription factor. If DNA is able to perform TQC, it would however seem very strange if it would be happy with this rather dull realization of other central functions of the genetic apparatus.

One can indeed consider besides the braids connecting DNA and its conjugate - crucial for the success of replication - also braids connecting DNA to mRNA and other forms of RNA, mRNA to tRNA, and tRNA to amino-acids. These braids would provide the topological realization of the genetic code and would increase dramatically the precision and effectiveness of the transcription and translation if these processes correspond to quantum transitions at the level of dark matter leading more or less deterministically to the desired outcome at the level of visible matter be it formation of DNA doublet strand, of DNA-mRNA association, of mRNA-tRNA association or tRNA-amino-acid association.

For instance, a temporary reduction of the value of Planck constant for these braids would contract these to such a small size that these associations would result with a high probability. The increase of Planck constant for braids could in turn induce the transfer of mRNA from the nucleus, the opening of DNA double strand during transcription and mitosis.

Also DNA-amino-acid braids might be possible in some special cases. The braiding between regions of DNA at which proteins bind could be a completely general phenomenon. In particular, the promoter region of gene could be connected by braids to the transcription factors of the gene and the halting of TQC computation to printing command could induce the reduction of Planck constant for these braids inducing the binding of the transcription factor binds to the promoter region. In a similar manner, the region of DNA at which RNA polymerase binds could be connected by braid strands to the RNA polymerase.

How braid color is represented?

If braid strands carry 4-color (A, T, C, G) then also lipid strands should carry this kind of 4-color. The lipids whose hydrophobic ends can be joined to form longer strand should have same color. This color need not be chemical in TGD Universe.

Only braid strands of the same color can be connected as TQC halts. This poses strong restrictions on the model.

1. Do braid strands appear as patches possessing same color?

Color conservation is achieved if the two lipid layers decompose in a similar manner into regions of fixed color and the 2-D flow is restricted inside this kind of region at both layers. A four-colored map of cell membrane would be in question! Liquid crystal structure [I4] applies only up to length scale of $L(151) = 10$ nm and this suggests that lipid layer decomposes into structural units of size $L(151)$ defining also cell membrane thickness. These regions might correspond to minimal regions of fixed color containing $N \sim 10^2$ lipids.

The controversial notion of lipid raft [I27] was inspired by the immiscibility of ordered and disordered liquid phases in a liquid model of membrane. The organization to connected regions of particular phase could be a phenomenon analogous to a separation of phases in percolation. Many cell functions implicate the existence of lipid rafts. The size of lipid rafts has remained open and could be anywhere between 1 and 1000 nm. Also the time scale for the existence of a lipid raft is unknown. A line tension between different regions is predicted in hydrodynamical model but not observed. If the decomposition into ordered and disordered phases is time independent, ordered phases could correspond to those involved with TQC and possess a fixed color. If disordered phases contain no braid strands the mixing of different colors is avoided. The problem with this option is that it restricts dramatically the possible braidings.

If one takes this option seriously, the challenge is to make patches and patch color (A, T, C, G) visible. Perhaps one could try to mark regions of portions of lipid layer by some marker to find whether the lipid layer decomposes to non-mixing regions.

Quantum criticality suggests that that the patches of lipid layer have a fractal structure corresponding to a hierarchy of TQC program modules. The hydrodynamics would be thus fractal: patches containing patches.... moving with respect to each other would correspond to braids containing braids containing... such that sub-braids behave as braid strands. In principle this is also a testable prediction.

2. Does braid color corresponds to some chemical property?

The conserved braid color is not necessary for the model but would imply genetic coding of the TQC hardware so that sexual reproduction would induce an evolution of TQC hardware. Braid color would also make the coupling of foreign DNA to the TQC performed by the organism difficult and realize an immune system at the level of quantum information processing.

The conservation of braid color poses however considerable problems. The concentration of braid strands of the same color to patches would guarantee the conservation but would restrict the possible braiding dramatically. A more attractive option is that the strands of same color find each other automatically by energy minimization after the halting of TQC. Electromagnetic Coulomb interaction would be the most natural candidate for the interaction in question. Braid color would define a faithful genetic code at the level of nucleotides. It would induce long range correlation between properties of DNA strand and the dynamics of cell immediately after the halting of TQC.

The idea that color could be a chemical property of phospholipids does not seem plausible. The lipid asymmetry of the inner and outer monolayers excludes the assignment of color to the hydrophilic groups PS, PI, PE, PCh. Fatty acids have $N = 14, ..., 24$ carbon atoms and $N = 16$ and 18 are the most common cases so that one could consider the possibility that the 4 most common feet pairs could correspond to the resulting combinations. It is however extremely difficult to understand how long range correlation between DNA nucleotide and fatty acid pair could be created.

3. Does braid color correspond to neutral quark pairs?

It seems that the color should be a property of the braid strand. In TGD inspired model of high T_c super-conductivity [K21] wormhole contacts having u and $\overline{d}$ and d and $\overline{u}$ quarks at the two wormhole throats feed electron's gauge flux to larger space-time sheet. The long range correlation between electrons of Cooper pairs is created by color confinement for an appropriate scaled up variant of chromo-dynamics which are allowed by TGD. Hence the neutral pairs of colored quarks whose members are located the ends of braid strand acting like color flux tube connecting the nucleotide to the lipid could code DNA color to QCD color.

For the pairs $u\overline{d}$ with net em charge the quark and anti-quark have the same sign of em charge and tend to repel each other. Hence the minimization of electro-magnetic Coulomb energy favors the neutral configurations $u\overline{u}$, $d\overline{d}$ and $u\overline{u}$, and $d\overline{d}$ coding for A, T, C, G in some order.

After the halting of TQC only these pairs would form with a high probability. The reconnection of the strands would mean a formation of a short color flux tube between the strands and the annihilation of quark pair to gluon. Note that single braid strand would connect DNA color and its conjugate rather than identical colors so that braid strands connecting two DNA strands (conjugate strands) should always traverse through an even (odd) number of cell membranes. The only plausible looking option is that nucleotides A, T, G, C are mapped to pairs of quark and anti-quarks at the ends of braid strand. Symmetries pose constraints on this coding.

1. By the basic assumptions charge conjugation must correspond to DNA conjugation so that one A and T would be coded to quark pair, say $q\overline{q}$ and its conjugate $\overline{q}q$. Same for C and G.

2. An additional aesthetically appealing working hypothesis is that *both* A and G with the same number of aromatic cycles (three) correspond to $q\overline{q}$ (or its conjugate).

   This would leave four options:

$$
\begin{array}{ll}
(A,G) \rightarrow (u\overline{u}, d\overline{d}) \ , & (T,C) \rightarrow (\overline{u}u, \overline{d}d) \ , \\
(A,G) \rightarrow (d\overline{d}, u\overline{u}) \ , & (T,C) \rightarrow (\overline{d}d), \overline{u}u) \ , \\
(T,C) \rightarrow (u\overline{u}, d\overline{d}) \ , & (A,G) \rightarrow (\overline{u}u, \overline{d}d) \ , \\
(T,C) \rightarrow (d\overline{d}, u\overline{u}) \ , & (A,G) \rightarrow (\overline{d}d), \overline{u}u) \ .
\end{array}
\tag{3.4.1}
$$

   It is an experimental problem to deduce which of these correspondences - if any - is realized.

Some general predictions

During TQC the lipids of the two lipid layers should define independent units of lipid hydrodynamics whereas after halting of TQC they should behave as single dynamical unit. Later it will be found that these two phases should correspond to high T_c superconductivity for electrons (Cooper pairs would bind the lipid pair to form single unit) and its absence. This prediction is testable.

The differentiation of cells should directly correspond to the formation of a mapping of a particular part of genome to cell membrane. For neurons the gene expression is maximal which conforms with the fact that neurons can have very large size. Axon might be also part of the map. Stem cells represent the opposite extreme and in this case minimum amount of genome should be mapped to cell membrane. The prediction is that the evolution of cell should be reflected in the evolution of the genome-membrane map.

Quantitative test for the proposal

There is a simple quantitative test for the proposal. A hierarchy of TQC programs is predicted, which means that the number of lipids in the nuclear inner membrane should be larger or at least of the same order of magnitude that the number of nucleotides. For definiteness take the radius of the lipid molecule to be about 5 Angstroms (probably somewhat too large) and the radius of the nuclear membrane about 2.5 μm.

For our own species the total length of DNA strand is about one meter and there are 30 nucleotides per 10 nm. This gives 6.3×10^7 nucleotides: the number of intronic nucleotides is only by few per cent smaller. The total number of lipids in the nuclear inner membrane is roughly 10^8. The number of lipids is roughly twice the number nucleotides. The number of lipids in the membrane of a large neuron of radius of order 10^{-4} meters is about 10^{11}. The fact that the cell membrane is highly convoluted increases the number of lipids available. Folding would make possible to combine several modules in sequence by the proposed connections between hydrophobic surfaces.

3.4.2 How Quantum States Are Realized?

Quantum states should be assigned to the ends of the braid strands and therefore to the nucleotides of DNA and conjugate DNA. The states should correspond to many-particle states of anyons and fractional electrons and quarks and anti-quarks are the basic candidates.

Anyons represent quantum states

The multi-sheeted character of space-time surface as a 4-surface in a book like structure having as pages covering spaces of the embedding space (very roughly, see the appendix) would imply additional degrees of freedom corresponding to the group algebra of the group $G \supset Z_n$ defining the covering. Especially interesting groups are tetra-hedral, octahedral, and icosahedral groups whose action does not map any plane to itself. Group algebra would give rise to $n(G)$ quantum states.

If electrons are labeled by elements of group algebra this gives $2^{n(G)}$-fold additional degeneracy corresponding to many-electron states at sheets of covering. The vacuum state would be excluded so that $2^{n(G)}-1$ states would result. If only Cooper pairs are allowed one would have $m_n = 2^{n(G)-1}-1$ states.

This picture suggests the fractionization of some fermionic charges such as em charge, spin, and fermion number. This aspect is discussed in detail in the Appendix. Single fermion state would be replaced by a set of states with fractional quantum numbers and one would have an analogy with the full electronic shell of atom in the sense that a state containing maximum number of anyonic fermions with the same spin direction would have the quantum numbers of the ordinary fermion.

One can consider two alternative options.

1. The fractionization of charges inspired the idea that catalytic hot spots correspond to "half" hydrogen bonds containing dark fractionally charged electron meaning that the Fermi sea for electronic anyons is not completely filled [K12]. The formation of hydrogen bond would mean a fusion of "half hydrogen bond" and its conjugate having by definition a compensating fractional charges guaranteeing that the net em charge and electron number of the resulting state are those of the ordinary electron pair and the state is stable as an analog of the full electron shell. Half hydrogen bonds would assign to bio-molecules "names" as sequences of half hydrogen bonds and only molecules whose "names" are conjugates of each other would form stable hydrogen bonded pairs. Therefore symbolic dynamics would enter the biology via bio-catalysis. Concerning quantum computation the problem is that the full shell assigned to hydrogen bond corresponds to only single state and cannot carry information.

2. The assignment of braids and fractionally charged anyonic quarks and anti-quarks would realize very similar symbolic dynamics. One cannot exclude the possibility that leptonic charges fractionize to same values as quark charges.

This suggest the following picture.

1. One could assign the fractional quantum numbers to the quarks and anti-quarks at the ends of the flux tubes defining the braid strands. This hypothesis is consistent with the correspondence between nucleotides and quarks and assigns anyonic quantum states to the ends of the braid. Wormhole magnetic fields would distinguish between matter in vivo and in vitro. This option is certainly favored by Occam's razor in TGD Universe.

2. Hydrogen bonds connect the DNA strands which suggests that fractionally charged quantum states at the ends of braids might be assignable to the ends of hydrogen bonds. The model for plasma electrolysis of Kanarev [L1] leads to a proposal that new physics is involved with hydrogen bonds. The presence of fractionally charged particles at the ends of bond might provide alternative explanation for the electrostatic properties of hydrogen bonds usually explained in terms of a modification electronic charge distribution by donor-acceptor mechanism. There would exists entire hierarchy of hydrogen bonds corresponding to the increasing values of Planck constant. DNA and even hydrogen bonds associated with water might correspond to a larger value of Planck constant for mammals than for bacteria.

3. The model for protein folding code [K7] leads to a cautious conclusion that flux tubes are prerequisites for the formation of hydrogen bonds although not identifiable with them. The model predicts also the existence of long flux tubes between acceptors of hydrogen bonds (such as $O =$, and aromatic rings assignable to DNA nucleotides, amino-acid backbone, phosphates, XYP, $X = A, T, G, C$, $Y = M, D, T$). This hypothesis would allow detailed identification of places to which quantum states are assigned.

Hierarchy of genetic codes defined by Mersenne primes

The model for the hierarchy of genetic codes inspires the question whether the favored values of $n(G) - 1$ correspond to Mersenne primes [A3]. **Table 3.1** lists the lowest hierarchies. Most of them are short.

$$\begin{array}{lll}
\{M_n\} & \{n(G)\} & \\
 & \{n_b\} & \\
\{2,7,127,2^{127}-1,?\} & \{4,8,128,2^{127},?\} & \{2,6,126,2^{126},?\} \\
\{5,31,2^{31}-1\} & \{6,32,2^{31}\} & \{4,30,2^{30}\} \\
\{13,2^{13}-1\} & \{14,2^{13}\} & \{12,2^{12}\} \\
\{17,2^{17}-1\} & \{18,2^{17}\} & \{16,2^{16}\} \\
\{19,2^{19}-1\} & \{20,2^{19}\} & \{18,2^{18}\} \\
\{61,2^{61}-1\} & \{62,2^{61}\} & \{60,2^{60}\} \\
\{89,2^{89}-1\} & \{90,2^{89}\} & \{88,2^{88}\} \\
\{107,2^{107}-1\} & \{108,2^{107}\} & \{106,2^{106}\}
\end{array} \tag{3.4.2}$$

Table 3.1: Hierachies of Mersenne primes

The number of states assignable to M_n is $M_n = 2^n - 1$ which does not correspond to full n bits: the reason is that one of the states is not physically realizable. 2^{n-1} states have interpretation as maximal number of statements consistent with an atomic statement (single bit fixed) and to $n_b = n - 1$ bits. **Table 3.1** lists the values of n_b for Mersenne primes.

Notice that micro-tubules decompose into 13 parallel helices consisting of 13 tubulin dimers. Could these helices with the conformation of the last tubulin dimer serving as a kind of parity bit realize M_{13} code?

There would be a nice connection with the basic phenomenology of ordinary computers. The value of the integer $n-1$ associated with Mersenne primes would be analogous to the number of bits of the basic information unit of processor. During the evolution of PCs it has evolved from 8 to 32 and is also power of 2.

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3.4.3 The Role Of High T_c Superconductivity In TQC

A simple model for braid strands leads to the understanding of how high T_c super conductivity assigned with cell membrane [K33] could relate to TQC. The most plausible identification of braid strands is as magnetic or wormhole magnetic flux tubes consisting of pairs of flux tubes connected by wormhole contacts whose throats carry fermion and anti-fermion such that their rotational motion at least partially generates the antiparallel magnetic fluxes at the two sheets of flux tube. The latter option is favored by the model of TQC but one must of course keep mind open for variants of the model involving only ordinary flux tubes. Both kinds of flux tubes can carry charged particles such as protons, electrons, and biologically important ions as dark matter with large Planck constant and the model for nerve pulse and EEG indeed relies on this assumption [K79].

Currents at space-like braid strands

If space-like braid strands are identified as idealized structures obtained from 3-D tube like structures by replacing them with 1-D strands, one can regard the braiding as a purely geometrical knotting of braid strands.

The simplest realization of the braid strand as magnetic flux tube would be as a hollow cylindrical surface connecting conjugate DNA nucleotide to cell membrane and going through 5- and/or 6- cycles associated with the sugar backbone of conjugate DNA nucleotides. The free electron pairs associated with the aromatic cycles would carry the current creating the magnetic field needed.

For wormhole magnetic flux one would have pair of this kind of hollow cylinders connected by wormhole contacts and carrying opposite magnetic fluxes. In this case the currents created by wormhole contacts would give rise to the antiparallel magnetic fluxes at the space-time sheets of wormhole contact and could serve as controllers of TQC. I have indeed proposed long time ago that so called wormhole Bose-Einstein condensates might be fundamental for the quantum control in living matter [K112]. In this case the presence of supra currents at either sheet would generate asymmetry between the magnetic fluxes.

There are two extreme options for both kinds of magnetic fields. For B-option magnetic field is parallel to the strand and vector potential rotates around it. For A-option vector potential is parallel to the strand and magnetic field rotates around it. The general case corresponds to the hybrid of these options and involves helical magnetic field, vector potential, and current.

1. For B-option current flowing around the cylindrical tube in the transversal direction would generate the magnetic field. The splitting of the flux tube would require that magnetic flux vanishes requiring that the current should go to zero in the process. This would make possible selection of a part of DNA strand participating to TQC.

2. For A-option the magnetic field lines of the braid would rotate around the cylinder. This kind of field is created by a current in the direction of cylinder. In the beginning of TQC the strand would split and the current of electron pairs would stop flowing and the magnetic field would disappear. Also now the initiation of computation would require stopping of the current and should be made selectively at DNA.

   The control of the TQC should rely on currents of electron pairs (perhaps Cooper pairs) associated with the braid strands. Supra currents would have quantized values and they are therefore very attractive candidates. The (supra) currents could also bind lipids to pairs so that they would define single dynamical unit in 2-D hydrodynamical flow. One can also think that Cooper pairs with electrons assignable to different members of lipid pair bind it to a single dynamical unit.

Do supra currents generate magnetic fields?

Energetic considerations favor the possibility that supra currents create the magnetic fields associated with the braid strands defined by magnetic flux tubes. In the case of wormhole magnetic flux tubes supra currents could generate additional magnetic fields present only at the second sheet of the flux tube.

Supra current would be created by a voltage pulse ΔV, which gives rise to a constant supra current after it has ceased. Supra current would be destroyed by a voltage pulse of opposite sign. Therefore voltage pulses could define an elegant fundamental control mechanism allowing to select the parts of genome participating to TQC. This kind of voltage pulse could be collectively initiated at cell membrane or at DNA. Note that constant voltage gives rise to an oscillating supra current.

Josephson current through the cell membrane would be also responsible for dark Josephson radiation determining that part of EEG which corresponds to the correlate of neuronal activity [K33] . Note that TGD predicts a fractal hierarchy of EEGs and that ordinary EEG is only one level in this hierarchy. The pulse initiating or stopping TQC would correspond in EEG to a phase shift by a constant amount

$$\Delta\Phi = Ze\Delta VT/\hbar \ ,$$

where T is the duration of pulse and ΔV its magnitude.

The contribution of Josephson current to EEG responsible for beta and theta bands interpreted as satellites of alpha band should be absent during TQC and only EEG rhythm would be present. The periods dominated by EEG rhythm should be observed as EEG correlates for problem solving situations (say mouse in a maze) presumably involving TQC. The dominance of slow EEG rhythms during sleep and meditation would have interpretation in terms of TQC.

Topological considerations

The existence of supra current requires that the flow allows for a complex phase $exp(i\Psi)$ such that supra current is proportional to $\nabla\Psi$. This requires integrability in the sense that one can assign to the flow lines of A or B (combination of them in the case of A-B braid) a coordinate variable Ψ varying along the flow lines. In the case of a general vector field X this requires $\nabla\Psi = \Phi X$ giving $\nabla \times X = -\nabla\Phi/\Phi$ as an integrability condition. This condition defines what is known as Beltrami flow [K17].

The perturbation of the flux tube, which spoils integrability in a region covering the entire cross section of flux tube means either the loss of super-conductivity or the disappearance of the net supra current. In the case of the A-braid, the topological mechanism causing this is the increase in the dimension of the CP_2 projection of the flux tube so that it becomes 3-D [K17], where I have also considered the possibility that 3-D character of CP_2 projection is what transforms the living matter to a spin glass type phase in which very complex self-organization patterns emerge. This would conform with the idea that in TQC takes place in this phase.

Fractal memory storage and TQC

If Josephson current through cell membrane ceases during TQC, TQC manifests itself as the presence of only EEG rhythm characterized by an appropriate cyclotron frequency. Synchronous neuron firing might therefore relate to TQC. The original idea that a phase shift of EEG is induced by the voltage initiating TQC - although wrong - was however useful in that it inspired the question whether the initiation of TQC could have something to do with what is known as a place coding by phase shifts performed by hippocampal pyramidal cells [J23, J27]. The playing with this idea provides important insights about the construction of quantum memories and demonstrates the amazing explanatory power of the paradigm once again.

The model also makes explicit important conceptual differences between TQC a la TGD and in the ordinary sense of wordin particular those related to different view about the relation between subjective and geometric time.

1. In TGD TQC corresponds to the unitary process U taking place following by a state function reduction and preparation. It replaces WCW (“world of classical worlds”) spinor field with a new one. WCW spinor field represent generalization of time evolution of Schrödinger equation so that a quantum jump occurs between entire time evolutions. Ordinary TQC corresponds to Hamiltonian time development starting at time $t = 0$ and halting at $t = T$ to a state function reduction.

2. In TGD the expression of the result of TQC is essentially 4-D pattern of gene expression (spiking pattern in the recent case). In usual TQC it would be 3-D pattern emerging as the computation halts at time t. Each moment of consciousness can be seen as a process in which a kind of 4-D statue is carved by starting from a rough sketch and proceeding to shorter details and building fractally scaled down variants of the basic pattern. Our life cycle would be a particular example of this process and would be repeated again and again but of course not as an exact copy of the previous one.

1. Empirical findings

The place coding by phase shifts was discovered by O′Reefe and Recce [J23]. In [J27] Y. Yamaguchi describes the vision in which memory formation by so called theta phase coding is essential for the emergence of intelligence. It is known that hippocampal pyramidal cells have “place property” being activated at specific “place field” position defined by an environment consisting of recognizable objects serving as landmarks. The temporal change of the percept is accompanied by a sequence of place unit activities. The theta cells exhibit change in firing phase distributions relative to the theta rhythm and the relative phase with respect to theta phase gradually increases as the rat traverses the place field. In a cell population the temporal sequence is transformed into a phase shift sequence of firing spikes of individual cells within each theta cycle.

Thus a temporal sequence of percepts is transformed into a phase shift sequence of individual spikes of neurons within each theta cycle along linear array of neurons effectively representing time axis. Essentially a time compressed representation of the original events is created bringing in mind temporal hologram. Each event (object or activity in perceptive field) is represented by a firing of one particular neuron at time τ_n measured from the beginning of the theta cycle. τ_n is obtained by scaling down the real time value t_n of the event. Note that there is some upper bound for the total duration of memory if scaling factor is constant.

This scaling down - story telling - seems to be a fundamental aspect of memory. Our memories can even abstract the entire life history to a handful of important events represented as a story lasting only few seconds. This scaling down is thought to be important not only for the representation of the contextual information but also for the memory storage in the hippocampus. Yamaguchi and collaborators have also found that the gradual phase shift occurs at half theta cycle whereas firings at the other half cycle show no correlation [J27] . One should also find an interpretation for this.

2. TGD based interpretation of findings

How this picture relates to TGD based 4-D view about memory in which primary memories are stored in the brain of the geometric past?

1. The simplest option is the initiation of TQC like process in the beginning of each theta cycle of period T and having geometric duration $T/2$. The transition $T \rightarrow T/2$ conforms nicely with the fundamental hierarchy of time scales comings as powers defining the hierarchy of measurement resolutions and associated with inclusions of hyperfinite factors of type II_1 [K110]. That firing is random at second half of cycle could simply mean that no TQC is performed and that the second half is used to code the actual events of "geometric now".

2. In accordance with the vision about the hierarchy of Planck constants defining a hierarchy of time scales of long term memories and of planned action, the scaled down variants of memories would be obtained by down-wards scaling of Planck constant for the dark space-time sheet representing the original memory. In principle a scaling by any factor $1/n$ (actually by any rational) is possible and would imply the scaling down of the geometric time span of TQC and of light-like braids. One would have TQC's inside TQC's and braids within braids (flux quanta within flux quanta). The coding of the memories to braidings would be an automatic process as almost so also the formation of their zoomed down variants.

3. A mapping of the time evolution defining memory to a linear array of neurons would take place. This can be understood if the scaled down variant (scaled down value of $\hbar$) of the space-time sheet representing original memory is parallel to the linear neuron array and contains at scaled down time value t_n a stimulus forcing n^{th} neuron to fire. The 4-D character of the expression of the outcome of TQC allows to achieve this automatically without complex program structure.

To sum up, it seems that the scaling of Planck constant of time like braids provides a further fundamental mechanism not present in standard TQC allowing to build fractally scaled down variants of not only memories but TQC's in general. The ability to simulate in shorter time scale is a certainly very important prerequisite of intelligent and planned behavior. This ability has also a space-like counterpart: it will be found that the scaling of Planck constant associated with space-like braids connecting bio-molecules might play a fundamental role in DNA replication, control of transcription by proteins, and translation of mRNA to proteins. A further suggestive conclusion is that the period T associated with a given EEG rhythm defines a sequence of TQC's having geometric span $T/2$ each: the rest of the period would be used to perceive the environment of the geometric now. The fractal hierarchy of EEGs would mean that there are TQC's within TQC's in a very wide range of time scales.

3.4.4 Codes And TQC

TGD suggests the existence of several (genetic) codes besides 3-codon code [K45, **?**]. The experience from ordinary computers and the fact that genes in general do not correspond to $3n$ nucleotides encourages to take this idea more seriously. The use of different codes would allow to tell what kind of information a given piece of DNA strand represents. DNA strand would be like a drawing of building containing figures (3-code) and various kinds of text (other codes). A simple drawing for the building would become a complex manual containing mostly text as the evolution proceeds: for humans 96 per cent of code would corresponds to introns perhaps obeying some other code.

The hierarchy of genetic codes is obtained by starting from n basic statements and going to the meta level by forming all possible statements about them (higher order logics) and throwing away one which is not physically realizable (it would correspond to empty set in the set theoretic realization). This allows $2^n - 1$ statements and one can select 2^{n-1} of statements consistent with atomic statement (one bit fixed) and say that these are true and give kind of axiomatics about world. The remaining statements are false. DNA would realize only these statements.

The hierarchy of Mersenne primes $M_n = 2^n - 1$ with $M_{n(next)} = M_{M_n}$ starting from $n = 2$ with $M_2 = 3$ gives rise to 1-code with 4 codons, 3-code with 64 codons, and $3 \times 21 = 63$-code with 2^{126} codons [K45] realized as sequences of 63 nucleotides (the length of 63-codon is about $2L(151)$, roughly twice the cell membrane thickness. It is not known whether this Combinatorial Hierarchy continues ad infinitum. Hilbert conjectured that this is the case.

In the model of pre-biotic evolution also 2-codons appear and 3-code is formed as the fusion of 1- and 2-codes. The problem is that 2-code is not predicted by the basic Combinatorial Hierarchy associated with $n = 2$.

There are however also other Mersenne hierarchies and the next hierarchy allows the realization of the 2-code. This Combinatorial Hierarchy begins from Fermat prime $n = 2^k + 1 = 5$ with $M_5 = 2^5 - 1 = 31$ gives rise to a code with 16 codons realized as 2-codons (2 nucleotides). Second level corresponds to Mersenne prime $M_{31} = 2^{31} - 1$ and a code with $2^{30=15\times 2}$ codons realized by sequences of 15 3-codons containing 45 nucleotides. This corresponds to DNA length of 15 nm, or length scale $3L(149)$, where $L(149) = 5$ nm defines the thickness of the lipid layer of cell membrane. $L(151) = 10$ nm corresponds to 3 full 2π twists for DNA double strand. The model for 3-code as fusion of 1- and 2-codes suggests that also this hierarchy - which probably does not continue further - is realized.

There are also further short Combinatorial hierarchies corresponding to Mersenne primes [A3].

1. $n = 13$ defines Mersenne prime M_{13}. The code would have $2^{12=6\times 2}$ codons representable as sequences of 6 nucleotides or 2 3-codons. This code might be associated with microtubuli.

2. The Fermat prime $17 = 2^4 + 1$ defines Mersenne prime M_{17} and the code would have $2^{16=8\times 2}$ codons representable as sequences of 8 nucleotides.

3. $n = 19$ defines Mersenne prime M_{19} and code would have $2^{18=9\times 2}$ codons representable as sequences of 9 nucleotides or three DNA codons.

4. The next Mersennes are M_{31} belonging to $n = 5$ hierarchy, M_{61} with $2^{60=30\times 2}$ codons represented by 30-codons. This corresponds to DNA length $L(151) = 10$ nm (cell membrane thickness). M_{89} (44-codons), M_{107} (53-codons) and M_{127} (belonging to the basic hierarchy) are the next Mersennes. Next Mersenne corresponds to M_{521} (260-codon) and to completely super-astrophysical p-adic length scale and might not be present in the hierarchy.

   This hierarchy is realized at the level of elementary particle physics and might appear also at the level of DNA. The 1-, 2-, 3-, 6-, 8-, and 9-codons would define lowest Combinatorial Hierarchies.

3.5 How To Realize The Basic Gates?

In order to have a more concrete view about realization of TQC, one must understand how quantum computation can be reduced to a construction of braidings from fundamental unitary operations. The article "Braiding Operators are Universal Quantum Gates" by Kaufmann and Lomonaco [B36] contains a very lucid summary of how braids can be used in topological quantum computation.

1. The identification of the braiding operator R - a unitary solution of Yang-Baxter equation - as a universal 2-gate is discussed. In the following I sum up only those points which are most relevant for the recent discussion.

2. One can assign to braids both knots and links and the assignment is not unique without additional conditions. The so called braid closure assigns a unique knot to a given braid by connecting n^{th} incoming strand to n^{th} outgoing strand without generating additional knotting. All braids related by so called Markov moves yield the same knot. The Markov trace (q-trace actually) of the unitary braiding S-matrix U is a knot invariant characterizing the braid closure.

3. Braid closure can be mimicked by a topological quantum computation for the original n-braid plus trivial n-braid and this leads to a quantum computation of the modulus of the Markov trace of U. The probability for the diagonal transition for one particular element of Bell basis (whose states are maximally entangled) gives the modulus squared of the trace. The closure can be mimicked quantum computationally.

3.5.1 Universality Of TQC

Quantum computer is universal if all unitary transformations of n^{th} tensor power of a finite-dimensional state space V can be realized. Universality is achieved by using only two kinds of gates. The gates of first type are single particle gates realizing arbitrary unitary transformation of $U(2)$ in the case of qubits. Only single 2-particle gate is necessary and universality is guaranteed if the corresponding unitary transformation is entangling for some state pair. The standard choice for the 2-gate is CNOT acting on bit pair (t,c). The value of the control bit c remains of course unchanged and the value of the target bit changes for $c=1$ and remains unchanged for $c=0$.

3.5.2 The Fundamental Braiding Operation As A Universal 2-Gate

The realization of CNOT or gate equivalent to it is the key problem in topological quantum computation. For instance, the slow de-coherence of photons makes quantum optics a promising approach but the realization of CNOT requires strongly nonlinear optics. The interaction of control and target photon should be such that for second polarization of the control photon target photon changes its direction but keeps it for the second polarization direction.

For braids CNOT can be expressed in terms of the fundamental braiding operation e_n representing the exchange of the strands n and $n+1$ of the braid represented as a unitary matrix R acting on $V_n \otimes V_{n+1}$.

The basic condition on R is Yang-Baxter equation expressing the defining condition $e_n e_{n+1} e_n = e_{n+1} e_n e_{n+1}$ for braid group generators. The solutions of Yang-Baxter equation for spinors are well-known and CNOT can be expressed in the general case as a transformation of form $A_1 \otimes A_2 R A_3 \otimes A_4$ in which single particle operators A_i act on incoming and outgoing lines. 3-braid is the simplest possible braid able to perform interesting TQC, which suggests that genetic codons are associated with 3-braids.

The dance of lipids on chessboard defined by the lipid layer would reduce R to an exchange of neighboring lipids. For instance, the matrix $R = DS$, $D = diag(1,1,1,-1)$ and $S = e_{11} + e_{23} + e_{32} + e_{44}$ the swap matrix permuting the neighboring spins satisfies Yang-Baxter equation and is entangling.

3.5.3 What The Replacement Of Linear Braid With Planar Braid Could-Mean?

Standard braids are essentially linear objects in plane. The possibility to perform the basic braiding operation for the nearest neighbors in two different directions must affect the situation somehow.

1. Classically it would seem that the tensor product defined by a linear array must be replaced by a tensor product defined by the lattice defined by lipids. Braid strands would be labelled by two indices and the relations for braid group would be affected in an obvious manner.

2. The fact that DNA is a linear structure would suggests that the situation is actually effectively one-dimensional, and that the points of the lipid layer inherit the linear ordering of nucleotides of DNA strand. One can however ask whether the genuine 2-dimensionality could provide a mathematical realization for possible long range correlations between distant nucleotides n and $n+N$ for some N. p-Adic effective topology for DNA might become manifest via this kind of correlations and would predict that N is power of some prime p which might depend on organism's evolutionary level.

3. Quantum conformal invariance would suggest effective one-dimensionality in the sense that only the observables associated with a suitably chosen linear braid commute. One might also speak about topological quantum computation in a direction transversal to the braid

strands giving a slicing of the cell membrane to parallel braid strands. This might mean an additional computational power.

4. Partonic picture would suggest a generalization of the linear braid to a structure consisting of curves defining the decomposition of membrane surface regions such that conformal invariance applies separately in each region: this would mean breaking of conformal invariance and 2-dimensionality in discrete sense. Each region would define a one parameter set of topological quantum computations. These regions might corresponds to genes. If each lipid defines its own conformal patch one would have a planar braid.

3.5.4 Single Particle Gates

The realization of single particle gates as $U(2)$ transformations leads naturally to the extension of the braid group by assigning to the strands sequences of group elements satisfying the group multiplication rules. The group elements associated with a n^{th} strand commute with the generators of braid group which do not act on n^{th} strand. G would be naturally subgroup of the covering group of rotation group acting in spin degrees of spin 1/2 object. Since $U(1)$ transformations generate only an overall phase to the state, the presence of this factor might not be necessary. A possible candidate for $U(1)$ factor is as a rotation induced by a time-like parallel translation defined by the electromagnetic scalar potential $\Phi = A_t$.

One of the challenges is the realization of single particle gates representing $U(2)$ rotation of the qubit. The first thing to come mind was that $U(2)$ corresponds to $U(2)$ rotation induced by magnetic field and electric fields. A more elegant realization is in terms of $SU(3)$ rotation, where $SU(3)$ is color group associated with strong interactions. This looks rather weird but there is direct evidence for the prediction that color $SU(3)$ is associated with TQC and thus cognition: something that does not come first in mind! I have myself written text about the strange finding of topologist Barbara Shipman suggesting that quarks are in some mysterious manner involved with honeybee dance and proposed an interpretation.

The realization of qubit as ordinary spin

A possible realization for single particle gate $s \subset SU(2)$ would be as $SU(2)$ rotation induced by a magnetic pulse. This transformation is fixed by the rotation axis and rotation angle around this axes. This kind of transformation would result by applying to the strand a magnetic pulse with magnetic field in the direction of rotation axes. The duration of the pulse determines the rotation angle. Pulse could be created by bringing a magnetic flux tube to the system, letting it act for the required time, and moving it away. $U(1)$ phase factor could result from the electromagnetic gauge potential as a non-integrable phase factor $exp(ie \int A_t dt/\hbar)$ coming from the presence of scale potential $\Phi = A_t$ in the Hamiltonian.

Conrete model for realization of 1-gates in terms of ordinary rotations

What could be the simplest realization of the $U(2)$ transformation in the case of cell membrane assuming that it corresponds to ordinary rotation?

1. There should be a dark spin 1/2 particle associated with each lipid, electron or proton most plausibly. TGD based model for high T_c superconductivity [K21] predicts that Cooper pairs correspond to pairs of cylindrical space-time sheets with electrons at the two space-time sheets. The size scale of the entire Cooper corresponds to p-adic length scale $L(151)$ defining the thickness of the cell membrane and cylindrical structure to $L(149)$, the thickness of lipid layer so that electrons are the natural candidates for TQC. The Cooper pair BE condensate would fuse the lipid pairs to form particles of lipid liquid.

2. Starting of TQC requires the splitting of electron Cooper pairs and its halting the formation of Cooper pairs again. The initiation of TQC could involve increase of temperature or an introduction of magnetic field destroying the Cooper pairs. Tqc could be also controlled by supra currents flowing along cylindrical flux tubes connecting 5- and/or aromatic cycles of conjugate DNA nucleotides to the cell membrane. The cutting of the current flow would make it possible for braid strand to split and TQC to begin.

3. By shifting a magnetic flux tube or sheet parallel to the cell membrane to the position of the portion of membrane participating to TQC is the simplest manner to achieve this. Halting could be achieved by removing the flux tube. The unitary rotation induced by the constant background magnetic field would not represent gate and it should be possible to eliminate its effect from TQC proper.

4. The gate would mean the application of a magnetic pulse much stronger than background magnetic field on the braid strands ending at the lipid layer. The model for the communication of sensory data to the magnetic body requires that magnetic flux tubes go through the cell membrane. This would suggest that the direction of the magnetic flux tube is temporarily altered and that the flux tube then covers part of the lipid for the required period of time.

   The realization of the single particle gates requires electromagnetic interactions. That single particle gates are not purely topological transformations could bring in the problems caused by a de-coherence due to electromagnetic perturbations. The large values of Planck constant playing a key role in the TGD based model of living matter could save the situation. The large value of $\hbar$ would be also required by the anyonic character of the system necessary to obtain R-matrix defining a universal 2-gate.

   The minimum time needed to inducing full 2π rotation around the magnetic axes would be essentially the inverse of cyclotron frequency for the particle in question in the magnetic field considered$T = 1/f_c = 2\pi m/ZeB$. For electrons in the dark magnetic field of $B = .2$ Gauss assigned to living matter in the quantum model of EEG this frequency would be about $f_c = .6$ MHz. For protons one would have $f_c = 300$ Hz. For a magnetic field of Tesla the time scales would be reduced by a factor 2×10^{-5}.

The realization of 1-gate in terms of color rotations

One can criticize the model of 1-gates based on ordinary spin. The introduction of magnetic pulses does not look an attractive idea and seems to require additional structures besides magnetic flux tubes (MEs?). It would be much nicer to assign the magnetic field with the flux tubes defining the braid strands. The rotation of magnetic field would however require changing the direction of braid strands. This does not look natural. Could one do without this rotation by identifying spin like degree of freedom in some other manner? This is indeed possible.

TGD predicts a hierarchy of copies of scaled up variants of both weak and color interactions and these play a key role in TGD inspired model of living matter. Both weak isospin and color isospin could be considered as alternatives for the ordinary spin as a realization of qubit in TGD framework. Below color isospin is discussed but one could consider also a realization in terms of nuclei and their exotic counterparts [L1], [L1] differing only by the replacement of neutral color bond between nuclei of nuclear string with a charged one. Charge entanglement between nuclei would guarantee overall charge conservation.

1. Each space-time sheet of braid strands contains quark and antiquark at its ends. Color isospin and hypercharge label their states. Two of the quarks of the color triplet form doublet with respect to color isospin and the third is singlet and has different hyper charge Y. Hence qubit could be realized in terms of color isospin I_3 instead of ordinary spin but third quark would be inert in the Boolean sense. Qubit could be also replaced with qutrit and isospin singlet could be identified as a statement with ill-defined truth value. Trits are used also in ordinary computers. In TGD framework finite measurement resolution implies fuzzy qubits and the third state might relate to this fuzziness. Also Gödelian interpretation can be consideredthe quark state with vanishing isospin would be associated with counterparts of undecidable propositions to which one cannot assign truth value (consider sensory input which is so ambiguous that one cannot tell what is there or a situation in which one cannot decide whether to do something or not). Note that hyper-charge would induce naturally the U(1) factor affecting the over all phase of qubit but affecting differently to the third quark.

2. Magnetic flux tubes are also color magnetic flux tubes carrying non-vanishing classical color gauge field in the case that they are non-vacuum extremals. The holonomy group of classical

color field is an Abelian subgroup of the $U(1)\times U(1)$ Cartan subgroup of color group. Classical color magnetic field defines the choice of quantization axes for color quantum numbers. For instance, magnetic moment is replaced with color magnetic moment and this replacement is in key role in simple model for color magnetic spin spin splittings between spin 0 and 1 mesons as well as spin 1/2 and 3/2 baryons.

3. There is a symmetry breaking of color symmetry to subgroup $U(1)_{I_3} \times U(1)_Y$ and color singletness is in TGD framework replaced by a weaker condition stating that physical states have vanishing net color quantum numbers. This makes possible the measurement of color quantum numbers in the manner similar to that for spin. For instance, color singlet formed by quark and antiquark with opposite color quantum numbers can in the measurement of color quantum numbers of quark reduce to a state in which quark has definite color quantum numbers. This state is a superposition of states with vanishing Y and I_3 in color singlet and color octet representations. Strong form of color confinement would not allow this kind of measurement.

4. Color rotation in general changes the directions of quantization axis of I_3 and Y and generates a new state basis. Since $U(1)\times U(1)$ leaves the state basis invariant, the space defined by the choices of quantization axes is 6-dimensional flag manifold $F = SU(3)/U(1) \times U(1)$. In contrast to standard model, color rotations in general do not leave classical electromagnetic field invariant since classical em field is a superposition of color invariant induced Kähler from and color non-invariant part proportional classical Z^0 field. Hence, although the magnetic flux tube retains its direction and shape in M^4 degrees of freedom, its electromagnetic properties are affected and this is visible at the level of classical electromagnetic interactions.

5. If color isospin defines the qubit or qutrit in topological quantum computation, color quantum numbers and the flag manifold F should have direct relevance for cognition. Amazingly, there is a direct experimental support for this! Years ago topologist Barbara Shipman made the intriguing observation that honeybee dance can be understood in terms of a model involving the flag manifold F [A5]. This led her to propose that quarks are in some mysterious manner involved with the honeybee dance. My proposal [K43] was that color rotations of the space-time sheets associated with neurons represent geometric information: sensory input would be coded to color rotations defining the directions of quantization axes for I_3 and Y. Subsequent state function reduction would provide conscious representations in terms of trits characterizing for instance sensory input symbolically.

   In [K43] I introduced the notions of geometric and sensory qualia corresponding to two choices involved with the quantum measurement: the choice of quantization axes performed by the measurer and the "choice" of final state quantum numbers in state function reduction. In the case of honeybee dance geometric qualia could code information about the position of the food source. The changes of color quantum numbers in quantum jump were identified as visual colors. In state function reduction one cannot speak about change of quantum numbers but about their emergence. Therefore one must distinguish between color qualia and the conscious experience defined by the emergence of color quantum numbers: the latter would have interpretation as qutrit.

Summarizing, this picture suggests that 1-gates of DNA TQC (understood as "dance of lipids") are defined by color rotations of the ends of space-like braid strands and at lipids. The color rotations would be induced by sensory and other inputs to the system. Topological quantum computation would be directly related to conscious experience and sensory and other inputs would fix the directions of the color magnetic fields.

Realization of braid operation in terms of $h_{eff} = n \times h$ hypothesis

This option would realize braiding as an analog for braiding for the degrees of freedom representable in terms of n-fold covering of embedding space (or space-time surfaces). The different branches of covering would relate to the branching of preferred extremal in n-furcation. Simplest n-furcation would corresponds to that resulting when 2π rotated space-time point no more corresponds to the original point (note that analog with Riemann surface associated with $z^{1/n}$. Similar phenomenon is possible in CP_2 degrees of freedom. The vision is that it is possible to construct dark k-particle states for $k \leq n$ in these discrete degrees of freedom so that discrete variant of second quantization would be in question.

Since large $h_{eff} = nh$ is highly favourable for TQC, the idea that living matter would perform TQC using dark matter phase. This option does not seem to be in conflict with the other option. One can in principle assign to each ordinary quantum state an $h_{eff} = nh$ and even allow the value of n to depend on the ordinary quantum numbers. By NMP state function reduction leads to one of these sub-spaces. As discussed, the outcome of TQC could be deduced by interaction free quantum measurement utilizing "externalized" state function reduction. It is of course not all obvious whether this procedure is equivalent with the standard one. The large value of h_{eff} would increase quantum coherence time and quantum coherence length associated with ordinary quantum numbers so that halting in this sense would be possible.

3.6 About Realization Of Braiding

The most plausible identification of braid strands is as magnetic or wormhole magnetic flux tubes. Flux tubes can contain charged particles such as protons, electrons, and biologically important ions as dark matter with large Planck constant and the model for nerve pulse and EEG indeed relies on this assumption [K79].

3.6.1 Could Braid Strands Be Split And Reconnect All The Time?

As far as braiding alone is considered, braid strands could be split all the time. This would require wormhole flux tubes if strands carry monopole flux. In other words, there would be no continuation of strands through the cell membrane. Computation would halt when lipids lose their unsaturated cis bonds so that they cannot follow the liquid flow. The conservation of strand color would be trivially true but would not have any implications. Supra currents would not be needed to control TQC and there would be no connection with generalized EEG. It is not obvious how the gene expression for the outcome of TQC could take place since the strands would not connect genome to genome. For these reasons this option does not look attractive.

The models for prebiotic evolution [K38, K39] and protein folding [K7] lead to a suggestion that braids can connect all kind of bio-molecules to each other and also water molecules and bio-molecules. Thus DNA TQC would represent only one example of TQC like activities performed by the living matter. The conclusion is that braidings are dynamical with reconnection of flux tubes representing a fundamental transformation changing the braiding and thus also TQC programs.

3.6.2 What Do Braid Strands Look Like?

In the following the anatomy of braid strands is discussed at general level and then and identification in terms of flux tubes of magnetic body is proposed.

Braid strands as nearly vacuum extremals

The braid strands should be nearly quantum critical sub-manifolds of $M^4 \times CP_2$ so that phase transitions changing Planck constant and thus their length can take place easily (DNA replication, binding of mRNA molecules to DNA during transcription, binding of transcription factors to promoters, binding of tRNA-amino-acid complexes to mRNA...).

Depending on whether phase transition takes place in M^4 or CP_2 degrees of freedom, either their M^4 projection belongs to $M^2 \subset M^4$ or their CP_2 projection to the homological trivial geodesic sphere $S^2 \subset CP_2$. In the latter case a vacuum extremal is in question. Maximal quantum criticality means $X^4 \subset M^2 \times S^2$ so that one has straight string with a vanishing string tension. The almost vacuum extremal property guarantees the braid strands can be easily generated from vacuum.

An additional requirement is that the gravitational mass is small. For objects of type $M^2 \times X^2_g$, $X^2_g \subset E^2 \times CP_2$, the gravitational mass vanishes for $g = 1$ (genus) and is of order CP_2 mass otherwise and negative for $g > 1$. Torus topology is the unique choice. A simple model for the braid strand is as a small non-vacuum deformation of $X^4 = M^2 \times X^2_g \subset M^2 \subset E^2 \times S^2$, $g = 1$.

As a special case one has $X^4 = M^2 \times S^1 \times S^1 \subset M^2 \subset E^2 \times S^1$, for which M^4 projection is a hollow cylinder, which could connect the aromatic 5- or 6-cycle of sugar backbone to another DNA strand, lipid, or amino-acid.

Braid strands as flux tubes of color magnetic body

One can make this model more detailed by feeding in simple physical inputs. The flux tubes carry magnetic field when the supra current is on. In TGD Universe all classical fields are expressible in terms of the four CP_2 coordinates and their gradients so that em, weak, color and gravitational fields are not independent as in standard model framework. In particular, the ordinary classical em field is necessarily accompanied by a classical color field in the case of non-vacuum extremals. This predicts color and ew fields in arbitrary long scales and quantum classical correspondence forces to conclude that there exists fractal hierarchy of electro-weak and color interactions.

Since the classical color gauge field is proportional to Kähler form, its holonomy group is Abelian so that effectively $U(1) \times U(1) \subset SU(3)$ gauge field is in question. The generation of color flux requires colored particles at the ends of color flux tube so that the presence of pairs of quark and antiquark assignable to the pairs of wormhole throats at the ends of the tube is unavoidable if one accepts quantum classical correspondence.

In the case of cell, a highly idealized model for color magnetic flux tubes is as flux tubes of a dipole field. The preferred axis could be determined by the position of the centrosomes forming a T shaped structure. DNA strands would define the idealized dipole creating this field: DNA is indeed negatively charged and electronic currents along DNA could create the magnetic field. The flux tubes of this field would go through nuclear and cell membrane and return back unless they end up to another cell. This is indeed required by the proposed model of TQC.

It has been assumed that the initiation of TQC means that the supra current ceases and induces the splitting of braid strands. The magnetic flux need not however disappear completely. As a matter fact, its presence forced by the conservation of magnetic flux seems to be crucial for the conservation of braiding. Indeed, during TQC magnetic and color magnetic flux could return from lipid to DNA along another space-time sheet at a distance of order CP_2 radius from it. For long time ago I proposed that this kind of structures -which I christened “wormhole magnetic fields” - might play key role in living matter [K112]. The wormhole contacts having quark and antiquark at their opposite throats and coding for A, T, C, G would define the places where the current flows to the “lower” space-time sheet to return back to DNA. Quarks would also generate the remaining magnetic field and supra current could indeed cease.

The fact that classical em fields and thus classical color fields are always present for non-vacuum extremals means that also the motion of any kind of particles (space-time sheets), say water flow, induces a braiding of magnetic flux tubes associated with molecules in water if the temporary splitting of flux tubes is possible. Hence the prerequisites for TQC are met in extremely general situation and TQC involving DNA could have developed from a much simpler form of TQC performed by water giving perhaps rise to what is known as water memory [I50, I51, I59, I60]. This would also suggest that the braiding operation is induced by the a controlled flow of cellular water.

3.6.3 How To Induce The Basic Braiding Operation?

The basic braiding operation requires the exchange of two neighboring lipids. After some basic facts about phospholipids the simplest model found hitherto is discussed.

Some facts about phospholipids

Phospholipids [I37] - which form about 30 per cent of the lipid content of the monolayer - contain phosphate group. The dance of lipids requires metabolic energy and the hydrophilic ends of the phospholipid could provide it. They could also couple the lipids to the flow of water in the vicinity of the lipid monolayer possibly inducing the braiding. Of course, the causal arrow could be also opposite.

The hydrophilic part of the phospholipid is a nitrogen containing alcohol such as serine, inositol or ethanolamine, or an organic compound such as choline. Phospholipids are classified into 3 kinds of phosphoglycerides [I36] and sphingomyelin.

1. Phosphoglycerides

In cell membranes, phosphoglycerides are the more common of the two phospholipids, which suggest that they are involved with TQC. One speaks of phosphotidyl X, where X= serine, inositol, ethanolamine is the nitrogen containing alcohol and X=Ch the organic compound. The shorthand notion OS, PI, PE, PCh is used.

The structure of the phospholipid is most easily explained using the dancer metaphor. The two fatty chains define the hydrophobic feet of the dancer, glycerol and phosphate group define the body providing the energy to the dance, and serine, inositol, ethanolamine or choline define the hydrophilic head of the dancer (perhaps "deciding" the dancing pattern).

There is a lipid asymmetry in the cell membrane. PS, PE, PI in cytoplasmic monolayer (alcohols). PC (organic) and sphingomyelin in outer monolayer. Also glycolipids are found only in the outer monolayer. The asymmetry is due to the manner that the phospholipids are manufactured.

[I35] [I35] in the inner monolayer is negatively charged and its presence is necessary for the normal functioning of the cell membrane. It activates protein kinase C which is associated with memory function. PS slows down cognitive decline in animals models. This encourages to think that the hydrophilic polar end of at least PS is involved with TQC, perhaps to the generation of braiding via the coupling to the hydrodynamic flow of cytoplasm in the vicinity of the inner monolayer.

2. Fatty acids

The fatty acid chains in phospholipids and glycolipids usually contain an even number of carbon atoms, typically between 14 and 24 making 5 possibilities altogether. The 16- and 18-carbon fatty acids are the most common. Fatty acids [I16] may be saturated or unsaturated, with the configuration of the double bonds nearly always cis.

The length and the degree of unsaturation of fatty acids chains have a profound effect on membranes fluidity as unsaturated lipids create a kink, preventing the fatty acids from packing together as tightly, thus decreasing the melting point (increasing the fluidity) of the membrane. The number of unsaturaded cis bonds and their positions besides the number of Carbon atoms characterizes the lipid. Quite generally, there are $3n$ Carbons after each bond. The creation of unsatured bond by removing H atom from the fatty acid could be an initiating step in the basic braiding operation creating room for the dancers. The bond should be created on both neighboring lipids simultaneously.

Could hydrodynamic flow induce braiding operations?

One can imagine several models for what might happen during the braiding operation in the lipid bilayer [I26]. One such view is following.

1. The creation of unsaturated bond and involving elimination of H atom from fatty acid would lead to cis configuration and create the room needed by dancers. This operation should be performed for both lipids participating in the braiding operation. After the braiding it might be necessary to add H atom back to stabilize the situation. The energy needed to perform either or both of these operations could be provided by the phosphate group.

2. The hydrophilic ends of lipids couple the lipids to the surrounding hydrodynamic flow in the case that the lipids are able to move. This coupling could induce the braiding. The primary control of TQC would thus be by using the hydrodynamic flow by generating localized vortices. There is considerable evidence for water memory [I50] but its mechanism remains to be poorly understood. If also water memory is realized in terms of the braid strands connecting fluid particles, DNA TQC could have evolved from water memory.

3. Sol-gel phase transition is conjectured to be important for the quantum information processing of cell [J3]. In the transition which can occur cyclically actin filaments (also at EEG frequencies) are assembled and lead to a gel phase resembling solid. Sol phase could correspond to TQC and gel to the phase following the halting of TQC. Actin filaments might be assignable with braid strands or bundles of them and shield the braiding. Also microtubules might shield bundles of braid strands.

4. Only inner braid strands are directly connected to DNA which also supports the view that only the inner monolayer suffers a braiding operation during TQC and that the outer mono-layer should be in a "freezed" state during it. There is a net negative charge associated with the inner mono-layer possibly relating to its participation to the braiding. The vigorous hydrodynamical flows known to take place below the cell membrane could induce the braiding.

3.6.4 Some Qualitative Tests

In life sciences the standard manner to test a model is to look whether the function of the system is affected in the predicted manner if one somehow interferes the system. Now interfering with TQC should affect the gene expression resulting otherwise.

1. Lipid layer hydrodynamics is predicted to allow two fundamental phases. The pairs of lipids should behave like single dynamical unit in super-conducting phase and as independent units in non-super-conducting phase. The application of magnetic field or increase of temperature should induce a transition between these two phases. These phase transitions applied selectively to the regions of cell membrane should affect gene expression. One could prevent halting of TQC by applying an external magnetic field and thus prevent gene expression. One could dream of deducing gene-membrane mapping with endoplasmic reticulum included.

2. The temperature range in which quantum critical high T_c super-conductivity is possible is probably rather narrow and should correspond to the temperature range in which cell membrane is functional. Brain is functional in a very narrow range of temperatures. Selective freezing of cell membrane might provide information about gene map provided by cell membrane.

3. One could do various things to the cell membrane. One could effectively remove part of it, freeze, or heat some part of the lipid liquid and look whether this has effects on gene expression. The known effects of ELF em fields on the behavior and physiology of vertebrates [K33] might relate to the fact that these fields interfere with TQC.

4. Artificially induced braiding by inducing a motion of lipids by some kind of stirring during TQC could induce/affect gene expression.

5. The application of external dark magnetic fields could affect gene expression. Tqc could be initiated artificially in some part of cell membrane by the application of dark magnetic field. Running TQC could be halted by an application of dark magnetic field interfering to zero with the background field. The application of magnetic pulses would affect TQC and thus gene expression. The problem is how to create dark magnetic fields in given length scale (range of magnetic field strength). Perhaps one could generate first ordinary magnetic field and then transform it to dark magnetic field by $\hbar$ changing phase transition. This could be achieved by a variation of some macroscopic parameters such as temperature, magnetic field strength, and analog of doping fraction appearing in standard high T_c super-conductivity.

6. Artificially induced scalings of $\hbar$ by varying temperature and parameters such as pH should induce or stop DNA replication, DNA-mRNA transcription and the translation of mRNA to proteins.

3.7 A Model For Flux Tubes

Biochemistry represents extremely complex and refined choreography. It is hard to believe that this reduces to a mere unconscious and actually apparent fight for chemical survival. In TGD Universe consciousness would be involved even at the molecular level and magnetic body would be the choreographer whose dance would induce the molecular activities. This picture combined with the idea of standard plugs and terminals at which flux tubes end, leads to a to a picture allowing to formulate a model for protein folding.

3.7.1 Flux Tubes As A Correlates For Directed Attention

Molecular survival is the standard candidate for the fundamental variational principle motivating the molecular intentional actions. There is entire hierarchy of selves and the survival at the higher level of hierarchy would force co-operation and altruistic behavior at the lower levels. One might hope that this hypothesis reduces to Negentropy Maximization Principle [K58], which states that the information contents of conscious experience is maximized. If this picture is accepted, the evolution of molecular system becomes analogous to the evolution of a society.

Directed attention is the basic aspect of consciousness and the natural guess would be that directed attention corresponds to the formation of magnetic flux tubes between subject and target. The directedness property requires some manner to order the subject and target.

1. The ordering by the values of Planck constant is what first comes in mind. The larger space-time sheet characterized by a larger value of Planck constant and thus at a higher level of evolutionary hierarchy would direct its attention to the smaller one.

2. Also the ordering by the value of p-adic prime characterizing the size scale of the space-time sheet could be considered but in this case directedness could be questioned.

3. Attention can be directed also to thoughts. Could this mean that attention is directed from real space-time sheets to p-adic space-time sheets for various values of primes but not vice versa? Or could the direction be just the opposite at least in the intentional action transforming p-adic space-time sheet to real space-time sheet? Perhaps directions are opposite for cognition.

The generation of (wormhole) magnetic flux tubes could be the correlate for the directed attention, not only at molecular level, but quite generally. Metaphorically, the strands of braid would be the light rays from the eyes of the perceiver to the target and their braiding would code the motions of the target to a topological quantum computation like activity and form a memory representation at least. The additional aspect of directed attention would be the coloring of the braid strands, kind of coloring for the virtual light rays emerging from the eyes of the molecular observer. In the case of DNA this can induce a coloring of braid strands emerging from amino-acids and other molecules so that it would indeed become possible to assign to free amino-acid the conjugate of the codon XYZ coding for it.

Attention can be also redirected. For this process there is a very nice topological description as a reconnection of flux tubes. What happens is that flux tubes $A \rightarrow B$ and $C \rightarrow D$ fuse for a moment and become flux tubes $A \rightarrow D$ and $C \rightarrow B$. This process is possible only if the strands have the same color so that the values of the quark charges associated with A and B are the same.

1. Reconnection process can modify TQC programs. For instance, in the case of the flux tubes coming from nucleotides X and X_c and ending to the lipid layer this process means that X and X_c and corresponding lipids become connected and genome builds memory representation about this process via similar link.

2. Reconnection process makes also possible what might be called color inheritance allowing amino-acids to inherit the conjugate colors of the nucleotides of the codon coding it.

3. DNA would have memory representation about molecular processes via these changing braiding topologies, and one could say that these molecular processes reflect the bodily motions of the magnetic body. Entire molecular dynamics of the organism could represent an enormous TQC induced by the motor activities of the magnetic body. At the level of sensory experience similar idea has been discussed earlier [K97]: out of body experiences (OBEs) and illusions such as train illusion could be understood in terms of motor action of magnetic body inducing virtual sensory percepts.

Attention can be also switched on and off. Here the structure of the lipid ends containing two nearby situated $=O$: s suggest the mechanism: the short flux tube connecting $=O$: s disappears by reconnection mechanism with a pair of hydrogen bonded water molecules leading to a shortcut of the connecting flux tubes to $=O--H_2O$ hydrogen bonds. The minimization of Coulomb interaction energy at each end implies that re-appearance of the flux tubes creates a short flux tube with the original strand color.

3.7.2 Does Directed Attention Generate Memory Representations And TQC Like Processes

Directed attention induces braiding if the target is moving and changing its shape. This gives rise to a memory representation of the behavior of the object of attention and also to a TQC like process. A considerable generalization of TQC paradigm suggests itself.

Tqc could be induced by the braiding between DNA and lipids, DNA and proteins via folding processes, DNA RNA braiding and braiding between DNA and its conjugate, DNA and protein braiding. The outcome of TQC would be represented as the temporal patterns of biochemical concentrations and rates and there would be hierarchy of p-adic time scales and those associated with the dark matter hierarchy.

For instance, the protein content of lipid membranes is about 50 per cent and varies between 25-75 per cent so that protein folding and lipid flow could define TQC programs as self-organization patterns. The folding of protein is dynamical process: alpha helices are created and disappear in time scale of 10^{-7} seconds and the side chains of protein can rotate.

The details of the TQC like process depend on what one assumes. The minimal scenario is deduced from the transcription and translation processes and from the condition that magnetic body keeps control or at least keeps book about what happens using genome as a tool. The picture would be essentially what one might obtain by applying a rough model for web in terms of nodes and links. The reader is encouraged to use paper and pencil to make the following description more illustrative.

1. Assume that mRNA and DNA remain connected by flux tubes after transcription and that only reconnection process can cut this connection so that mRNA inherits the conjugate colors of DNA. Assume same for mRNA and tRNA. Assume that amino-acid associated with tRNA has similar flux tube connections with the nucleotides of tRNA. Under these assumptions amino-acid inherits the conjugate colors of DNA nucleotides via the connection line DNA-mRNA-tRNA-amino-acid faith-fully if all links are correspond to quark pairs rather than their superpositions. Wobble pairing for Z nucleotide could actually correspond to this kind of superposition.

2. One can consider several options for the amino-acid-acid DNA correspondence but trial-and-error work showed that a realistic folding code is obtained only if X, Y, and Z correspond to $O-H$, $O=$, and NH_2 in the constant part of free amino-acid. During translation the formation of the peptide bond between amino-acids dehydration leads to a loss of $O-H$ and one H from NH_2. The flux tube from tRNA to $O-H$ becomes a flux tube to water molecule inheriting the color of X so that $O=-NH_2$ of the amino-acid inside protein represents the conjugate of YZ.

3. Hydrogen bonding between $O=$ and NH of n: th and $n+k$: th amino-acids inside alpha helices and n: th and $n+1$: th amino-acids inside beta strands reduces effectively to base pairing characterized by $Y=Z$ rule. Assuming that flux tube is only a prerequisite for the formation of hydrogen bond, $Y(n)=Z(n+k)$ or $Z(n)=Y(n+k)$ allows the existence of hydrogen bond. The identification of hydrogen bond with flux tube gives a more stringent condition $Y(n)=Z(n+k)$. The first option is favored. Either condition is extremely restrictive condition on the gene coding the amino-acid unless one assumes quantum counterpart of wobble base pairing for mRNA or tRNA-amino-acid pairing in the case of Z nucleotide (as one indeed must do). Note that the $O=$ atom of the amino-acid is in a special role in that it can have hydrogen bond flux tubes to donors and flux tube connections with $O=$: s of other amino-acids, the residues of amino-acids containing acceptors (say $O=$ or aromatic ring), and with the aromatic rings of say ATP.

4. The recombination process for two conjugate DNA-mRNA-tRNA-amino-acid links can transform the flux tubes in such manner that one obtains link between the $=O$: s of amino-acids A_1 and A_2 characterized by Y and Y_c. Besides hydrogen bonding this mechanism could be central in the enzyme substrate interaction. The process would pair tRNAs corresponding to Y and Y_c together to give DNA-mRNA-tRNA-tRNA-mRNA-DNA link providing a memory representation about amino-acid pairing A_1-A_2. One could say that magnetic body

creates with the mediation of the genome dynamical TQC programs to which much of the bio-molecular activity reduces. Not all however, since two amino-acid pairs $A_1 - A_2$ and $A_3 - A_4$ can recombine to $A_1 - A_4$ and $A_3 - A_2$ without DNA knowing anything about it. Magnetic body would however know.

5. The constant part of non-hydrogen bonded amino-acid inside protein would behave like Y_cZ_c if amino-acid is coded by XYZ. The $COOH$ end of protein would behave like $X_cY_cZ_c$. Also flux tubes connecting the residue groups become possible and protein does not behave like single nucleotide anymore. By color inheritance everything resulting in the reconnection process between $O =$ and NH_2 and residues reduces in a well-defined sense to the genetic code.

3.7.3 Realization Of Flux Tubes

The basic questions about flux are following. Where do they begin, where do they end, and do they have intermediate plugs which allow temporary cutting of the flux tube.

Where do flux tubes begin from?

The view about magnetic body as a controller of biological body using genome as a control tool suggests that DNA is to a high degree responsible for directed attention and other molecules as targets so that flux tubes emanate from DNA nucleotides. The reason would be that the aromatic cycles of DNA correspond to larger value of Planck constant. Some chemical or geometric property of DNA nucleotides or of DNA nucleotides of DNA strand could raise them to the role of subject. Aromatic cycle property correlates with the symmetries associated with large value of Planck constant and is the best candidate for this property.

If this picture is accepted then also some amino-acid residues might act as subjects/objects depending on the option. Phe, His, Trp, Tyr contain aromatic cycle. The derivatives of Trp and Tyr act as neurotransmitters and His is extremely effective nucleophilic catalyst. This would make possible more specific catalytic mechanisms through the pairing of Phe, His, Trp, and Tyr with residues having flux tube terminals.

This raises the question about the physical interaction determining the color of the strand emerging from the aromatic cycle. The interaction energy of quark at the end of flux tube with the classical electromagnetic fields of nuclei and electrons of the ring should determine this. The wormhole contact containing quark/antiquark at the throat at space-time sheet containing nuclei and electrons could also de-localize inside the ring. One of the earliest hypothesis of TGD inspired model for living matter was that wormhole Bose-Einstein condensates could be crucial for understanding of the behavior of biomolecules [K112]. Wormhole throats with quark and antiquark at their throats appear also in the model of high T_c superconductivity [K21]. As far as couplings are considered, these wormhole contacts are in many respects analogous to the so called axions predicted by some theories of elementary particle physics. The wormhole contact like property is by no means exceptional: all gauge bosons correspond to wormhole contacts in TGD Universe.

The only manner for the electronic space-time sheet to feed its electromagnetic gauge flux to larger space-time sheets using exactly two wormhole contacts is to use wormhole contacts with $\overline{u}$ and d at their "upper" throat (T, G). For proton one would have $\overline{d}$ and u at their "upper" throat (A, C). The presence of electron or proton at nucleotide space-time sheet near the end of flux tube might allow to understand the correlation. The transfer of electrons and protons between space-time sheets with different p-adic length scale is basic element of TGD based model of metabolism so that there might be some relation.

Acceptors as plugs and donors as terminals of flux tubes?

Standardization constraint suggests that flux tubes are attached to standard plugs and terminals. The explicit study of various biological molecules and the role of water in biology gives some hints.

1. An attractive idea is that $= O$ serves as a plug to which flux arrives and from which it can also continue. For the minimal option suggested by hydrogen bonding $O =$ could be connected to two donors and $O =$ could not be connected to $O =$. The assumption that the

flux tube can connect also two $O =$: s represents a hypothesis going outside the framework of standard physics. A stronger assumption is that all acceptors can act as plugs. For instance, the aromatic rings of DNA nucleotides could act as acceptors and be connected to a sequence of $O =$ plugs eventually terminating to a hydrogen bond.

2. Donors such as $O - H$ would in turn correspond to a terminal at which flux tube can end. One might be very naïve and say that conscious bio-molecules have learned the fundamental role of oxygen and water in the metabolism and become very attentive to the presence of $= O$ and $O - H$. $= O$ appears in $COOH$ part of each amino-acid so that this part defines the standard plug. $= O$ appears also in the residues of Asp, Glu, Asn, Gln. $O - H$ groups appear inside the residues of Asp, Glu and Ser, Thr.

3. Hydrogen bonds $X - H - -Y$ have the basic defining property associated with directed attention, namely the asymmetry between donor X and acceptor Y. Hence there is a great temptation consider the possibility that hydrogen bonds correspond to short flux tubes, that flux tubes could be seen as generalized hydrogen bonds. Quite generally, Y could be seen as the object of directed attention of X characterized by larger value of Planck constant. The assumption that two $O =$: s, or even two acceptors of a hydrogen bond, can be connected by a flux tube means more than a generalization of hydrogen bond the connection with a donor would correspond only to the final step in the sequence of flux tubes and plugs giving rise to a directed attention.

4. This hypothesis makes the model rather predictive. For instance, $N - H$, NH_2, $O - H$ and much less often $C - H$ and $S - H$ are the basic donors in the case of proteins whereas $O =$, $-O-$, $-N = S - S$, $-S^-$ and aromatic rings are the basic acceptors. Reconnection process should be involved with the dynamics of ordinary hydrogen bonding. Reconnection process implies inheritance of the flux tube color and means a realization of the symbol based dynamics. It turns out that this hypothesis leads to a model explaining basic qualitative facts about protein folding.

3.7.4 Flux Tubes And DNA

The model of DNA as topological quantum computer gives useful guide lines in the attempt to form a vision about flux tubes. It was assumed that braid strands defined by "wormhole magnetic" flux tubes join nucleotides to lipids and can continue through the nuclear or cell membrane but are split during TQC. The hydrophilic ends of lipids attach to water molecules and self-organization patterns for the water flow in gel phase induce a 2-D flow in the lipid layer which is liquid crystal defining TQC programs at the classical level as braidings. The flow indeed induces braiding if one assumes that during topological computation the connection through the cell membrane is split and reconnected after the halting of TQC.

The challenge is to understand microscopically how the flux tube joins DNA nucleotide to the phospholipid [I38]. Certainly the points at which the flux tubes attach should be completely standard plugs and the formation of polypeptide bonds is an excellent guide line here. Recall that phospholipid, the TQC dancer, has two hydrophobic legs and head. Each leg has at the hydrophilic end O=C-O-C part joining it to glyceride connected to monophosphate group in turn connected to a hydrophilic residue R. The most often appearing residues are serine, inositol, ethanolamine, and choline. Only three of these appear in large quantities and there is asymmetry between cell exterior and interior.

Let us denote by $= O_1$ and $= O_2$ the two oxygens (maybe analogs of right and left hemispheres!) in question. The proposal is that DNA nucleotide and $= O_1$ are connected by a flux tube: the asymmetry between right and left lipid legs should determine which of the legs is "left leg" and which $O =$ is the "left brain hemisphere". $= O_2$, the "holistic right brain hemisphere", connects in turn to the flux tube coming from the other symmetrically situated $= O_2$ at the outer surface of the second lipid layer. Besides this $= O_1$ and $= O_2$ are connected by a flux tube serving as switch on both sides of the membrane.

During TQC the short $O = -O =$ flux tube would experience reconnection with a flux tube acting as hydrogen bond between water molecules so that the connection is split and $O =$: s form hydrogen bonds. The reversal of this reconnection creates the connection again and halts the computation. The lipid residue R couples with the flow of the liquid in gel phase. Since $= O$ is in question the quark or antiquark at the end can correspond to the DNA nucleotide in question. The necessary complete correlation between quark and antiquark charges at the ends of flux tubes associated with $= O_1$ and $= O_2$ can be understood as being due to the minimization of Coulomb interaction energy.

If one is ready to accept magnetic flux tubes between all acceptors then the aromatic rings of nucleotides known to be acceptors could be connected by a flux tube to the $O =$ atom of the lipid or to some intermediate $O =$ atom. The phosphate groups associated with nucleotides of DNA strand contain also $= O$, which could act as a plug to which the flux tube from the nucleotide is attached. The detailed charge structure of the aromatic ring(s) should determine the quark-nucleotide correspondence. The connection line to the lipid could involve several intermediate $O =$ plugs and the first plug in the series would be the $O =$ atom of the monophosphate of the nucleotide.

There is a strong temptation to assume that subset of XYP molecules, $X = A, G, T, C$, $Y = M, D, T$ act as standard plugs with X and phosphates connected by flux tubes to a string. This would make possible to engineer braid strands from standard pieces connected by standard plugs. DNA nucleotide XMP would have flux tube connection to the aromatic ring of X and the $O =$ of last P would be connected to next plug of the communication line. If so, a close connection with metabolism and topological quantum computation would emerge. Phosphorylation would be an absolutely essential for both metabolism and buildup of connection lines acting as braid strands. $O = -O =$ flux tubes could also act as switches inducing a shortcut of the flux tube connection by reconnecting with a hydrogen bond connecting two water molecules. This is an essential step in the model for how DNA acts as topological quantum computer.

This picture would fit with the fact that XYP molecules, in particular AMP, ADP, and ATP, appear in bio-molecules involved with varying functions such as signalling, control, and metabolism. $= O$ might act as a universal plug to which flux tubes from electronegative atoms of information molecules can attach their flux tubes. This would also provide a concrete realization of the idea that information molecules (neurotransmitters, hormones) are analogous to links in Internet [K79]: they would not represent the information but establish a communication channel. The magnetic flux tube associated with the information molecule would connect it to another cell and by the join to $= O$ plug having flux tube to another cell, say to its nucleus, would create a communication or control channel.

3.7.5 Introns And DNA-Protein Attachment

An example is the situation in which protein acts as an enzyme attaching on DNA. Suppose that this process effectively reduces to a base pairing between amino-acid and DNA nucleotide. Protein can attach to any portion of DNA. The simplest interaction is the attachment to the gene coding for the amino-acid itself but much more general enzymatic interactions are possible. It must be however noticed that DNA sequence coding for given amino-acid sequences is considerably longer than amino-acid sequence: the sequence coding for 10 amino-acids is about 10 nm long whereas the corresponding straight amino-acid strand is about 4.7 nm long. It is known that DNA can change its conformation from strand during enzyme-DNA action [I90], and the contraction of DNA strand might make possible to have enzyme-DNA interaction involving fusion along several subsequent amino-acids. This kind of mechanism might work also in the case that attachment region corresponds to several exons. There is however no need to assume that subsequent amino-acids are form a contact with DNA.

One can of course ask whether genes containing introns tend to code for proteins which are used for topological quantum computations. Introns, perhaps the repeating sequences with no obvious function, would have at least this useful function but very probably much more useful ones too (they are now known to be transcribed to RNA and TGD suggest that language corresponds to intronic gene expression). The emergence of introns might be somewhat like the emergence of information society.

The folding of proteins tends to be conserved in the evolution whereas primary structure can change quite a lot apart from some amino-acids critical for enzymatic action. This confirms with the effective base pairing interaction between amino-acids and DNA to be discussed later and would mean that DNA-amino-acid TQC programs are rather robust against mutations.

Flux tubes and DNA

The model of DNA as topological quantum computer gives useful guide lines in the attempt to form a vision about flux tubes. It was assumed that braid strands defined by "wormhole magnetic" flux tubes join nucleotides to lipids and can continue through the nuclear or cell membrane but are split during TQC. The hydrophilic ends of lipids attach to water molecules and self-organization patterns for the water flow in gel phase induce a 2-D flow in the lipid layer which is liquid crystal defining TQC programs at the classical level as braidings. The flow indeed induces braiding if one assumes that during topological computation the connection through the cell membrane is split and reconnected after the halting of TQC.

The challenge is to understand microscopically how the flux tube joins DNA nucleotide to the phospholipid [I37]. Certainly the points at which the flux tubes attach should be completely standard plugs and the formation of polypeptide bonds is an excellent guide line here. Recall that phospholipid, the TQC dancer, has two hydrophobic legs and head. Each leg has at the hydrophilic end O=C-O-C part joining it to glyceride connected to monophosphate group in turn connected to a hydrophilic residue R. The most often appearing residues are serine, inositol, ethanolamine, and choline. Only three of these appear in large quantities and there is asymmetry between cell exterior and interior.

1. Are the flux tubes beginning from O=: s special?

Let us denote by $=O_1$ and $=O_2$ the two oxygens (maybe analogs of right and left hemispheres!) in question.

1. The proposal is that DNA nucleotide and $=O_1$ are connected by a flux tube: the asymmetry between right and left lipid legs should determine which of the legs is "left leg" and which $O=$ is the "left brain hemisphere". $=O_2$, the "holistic right brain hemisphere", connects in turn to the flux tube coming from the other symmetrically situated $=O_2$ at the outer surface of the second lipid layer. Besides this $=O_1$ and $=O_2$ are connected by a flux tube serving as switch on both sides of the membrane.

2. During TQC the short $O=-O=$ flux tube would experience reconnection with a flux tube acting as hydrogen bond between water molecules so that the connection is split and $O=$: s form hydrogen bonds. The reversal of this reconnection creates the connection again and halts the computation. The lipid residue R couples with the flow of the liquid in gel phase. Since $=O$ is in question the quark or antiquark or a pair of electron pairs at the end can correspond to the DNA nucleotide in question. The necessary complete correlation between quark and antiquark charges at the ends of flux tubes associated with $=O_1$ and $=O_2$ might be understood as being due to the minimization of Coulomb interaction energy. In the case of pair of electron pairs the correlation could come from the minimization of the magnetic energy.

3. If one is ready to accept magnetic flux tubes between all acceptors then the aromatic rings of nucleotides known to be acceptors could be connected by a flux tube to the $O=$ atom of the lipid or to some intermediate $O=$ atom. The phosphate groups associated with nucleotides of DNA strand contain also $=O$, which could act as a plug to which the flux tube from the nucleotide is attached. The detailed charge structure of the aromatic ring(s) should determine the quark-nucleotide correspondence. The connection line to the lipid could involve several intermediate $O=$ plugs and the first plug in the series would be the $O=$ atom of the monophosphate of the nucleotide.

There is a strong temptation to assume that subset of XYP molecules, $X = A, G, T, C$, $Y = M, D, T$ act as standard plugs with X and phosphates connected by flux tubes to a string. This would make it possible to engineer braid strands from standard pieces connected by standard plugs. DNA nucleotide XMP would have flux tube connection to the aromatic ring of X and the $O=$ of last P would be connected to next plug of the communication line. If so, a close connection with metabolism and topological quantum computation would emerge.

1. Phosphorylation [I39] would be an absolutely essential for both metabolism and buildup of connection lines acting as braid strands. Phosphorylation is indeed known to be the basic

step activating enzymes. In eukaryotes the phosphorylation takes plane amino-acids most often for ser but also thr, and trp with aromatic rings are phosphorylated. Mitochondrions have specialized to produce ATP in oxidative phosphorylation from ADP and photosynthesis produces ATP. All these activities could be seen as a production of standard plugs for braid strands making possible directed attention and quantum information processing at molecular level.

2. As already noticed, $O = -O =$ flux tubes could also act as switches inducing a shortcut of the flux tube connection by reconnecting with a hydrogen bond connecting two water molecules. This is an essential step in the model for how DNA acts as topological quantum computer. De-phosphorylation might be standard manner to realize this process.

3. This picture would fit with the fact that XYP molecules, in particular AMP, ADP, and ATP, appear in bio-molecules involved with varying functions such as signalling, control, and metabolism. $= O$ might act as a universal plug to which flux tubes from electronegative atoms of information molecules can attach their flux tubes. This would also provide a concrete realization of the idea that information molecules (neurotransmitters, hormones) are analogous to links in Internet [K79]: they would not represent the information but establish a communication channel. The magnetic flux tube associated with the information molecule would connect it to another cell and by the join to $= O$ plug having flux tube to another cell, say to its nucleus, would create a communication or control channel.

2. DNA as topological quantum computer hypothesis and electronic super-conductivity

The vision about DNA as topological quantum computer is very general. The essential element is the coding of DNA nucleotides and one can imagine several options.

1. One realization is based on the representation of DNA nucleotides A, T, C, G as quarks u, d and their antiquarks and requires scaled up version of QCD. The motivation for this realization came from the observation of Barbara Shipman that the mathematical description of honeybee dance suggests that quarks play a role in living matter [A5].

2. Second option that one can imagine would use spin 1 triplet and spin 0 singlet of dark electron pair. Spin 0 state for electron pair however gives rise to vanishing dipole field so that flux tube structure would not be possible. Can one circumvent this option or are quark pairs unavoidable?

3. DNA as TQC lead to the hypothesis that it is O= to which one must assign the flux tube pair responsible for the representation of the genetic code. Why O= would be in special role?

   (a) If there are two parallel flux tubes, one obtains tensor product $3 \times 3 = 5 + 3 + 1$ of electron triplets at the ends of the flux tubes. Could it be that A, T, C, and G are represented in terms of 3 and 1 and the breaking of rotational invariance implies a mixing of singlet and spin 0 state of triplet so that nucleotides and their conjugates could correspond to the resulting two pairs related by reflection?

   One can however argue that for $S_z = 0$ states the direction of the magnetic flux tubes is orthogonal to that in other cases. An alternative possibility is that one uses only the four $S_z \neq 0$ states of spin 2 5-multiplet obtained in the tensor product. The breaking of the full rotational symmetry down to SO(2) symmetry around flux tube direction could be used to justify this option.

   (b) The coding would be also consistent with quantum classical correspondence since it would reduce at classical level to a coding in terms of directions of magnetic fields in the two flux tubes: the directions could be parallel and in two directions or antiparallel giving also two options: four altogether. Notice however that one must be able to distinguish between two different configurations in which the directions of magnetic flux are opposite for the flux tubes of the pair. Classically this is achieved if the flux tubes form either a right-handed or left-handed double helix. Double helix could also resolve the problem posed by the fact that in $S_z = 0$ case the flux tubes cannot be parallel to their common axis at the flux tube end.

(c) This option would allow a unification of DNA as topological quantum computer conjecture with the conjectures about dark high T_c super-conductivity and negentropic entanglement.

$ATP \rightarrow ADP + P_i$ would correspond to the fusion of flux tube pair with two hydrogen bonds associated with water molecules so what they could become short-circuited with water molecules. The reverse process would create flux tube connection labelled by the spin state equivalent of A, T, C, or G. The possibility of 5-plet allows also to consider the possibility of five codons instead of four.

Whatever the correct option is it must explain how the correspondence between A, T, C, G and secondary codons emerges.

1. If the pairs of spin triplet electron pairs appear in the correspondence, one must understand why the spin state of the pair of electron pairs at the O= of the phosphate attached with the DNA nucleotide correlates with the character of the nucleotide. Phosphate has also two O^-: s containing two electron pairs. Minimization of the magnetic energy is the explanation which is easiest to imagine. Maybe the total magnetic energy of the pair in the magnetic field of the flux tube structure assignable to the nucleotide plus the de-oxyribose preceding it. T and C contain also O= but not A and G. and A and T and C and G are conjugates.

   By studying the chemical structure of DNA (see `http://tinyurl.com/yd7b7w98`) [I66] one finds that the pairs AT and CG contain two O=: s which belong either to same nucleotide (to T in A-T) or to different nucleotides (C-G). This suggests the coding in which there are flux tube pairs connecting the two phosphate O=s at the two sides of the double strand and going through the two intermediation O=s. The rule would be that the spin states are conjugates at the ends of the flux tubes. A-T and T-A pairs could correspond to parallel flux tubes with same direction of the flux and G-C and C-G to parallel flux tubes with opposite directions of the magnetic fluxes.

2. If quark pairs are unavoidable, the correspondence of A, T, C, G with quarks and antiquark must relate to quark charges coming as $\pm 2/3$, $\pm 1/3$. Also in this case the coding mechanism based on the flux tubes connecting O=: s is natural.

The conclusion would be that the original view about secondary realization of genetic code can be replaced with the realization based on spin 1 dark Cooper pairs of electrons between which the entanglement is negentropic. Quark color plays no special role in the model of DNA as topological quantum computer [K3] so that the model remains as such. One implication would be however that the magnetic flux tubes carrying dark electron pairs at their ends could be of astrophysical size.

3.7.6 Some Predictions Related To The Representation Of Braid Color

Even in the rudimentary form discussed above the model makes predictions. In particular, the hypothesis that neutral quark pairs represent braid color is easily testable.

Anomalous em charge of DNA as a basic prediction

The basic prediction is anomalous charge of DNA. Also integer valued anomalous charge for the structural units of genome is highly suggestive.

The selection of the working option - if any such exists - is indeed experimentally possible. The anomalous charge coupling to the *difference* of the gauge potentials at the two space-time sheets defines the signature of the wormhole contact at the DNA end of braid strand. The effective (or anomalous) em charge is given as sum of quark charges associated with DNA space-time sheet:

$$Q_a = [n(A) - n(T)]Q(q_A) + [n(G) - n(C)]Q(q_G) \quad (3.7.1)$$

is predicted. The four possible options for charge are given explicitly in **Table 3.2**.

$$
\begin{aligned}
Q_a &= [n(A) - n(T)]\tfrac{2}{3} - [n(G) - n(C)]\tfrac{1}{3} \ , \\
Q_a &= -[n(A) - n(T)]\tfrac{1}{3} + [n(G) - n(C)]\tfrac{2}{3} \ , \\
Q_a &= -[n(A) - n(T)]\tfrac{2}{3} + [n(G) - n(C)]\tfrac{1}{3} \ , \\
Q_a &= [n(A) - n(T)]\tfrac{1}{3} - [n(G) - n(C)]\tfrac{2}{3} \ .
\end{aligned}
\tag{3.7.2}
$$

Table 3.2: Table show four possible options for em charge as sum of quark charges.

Second option is obtained from the first option $(A, T, G, C) \rightarrow (u, \overline{u}, d, \overline{d})$ by permuting u and d quark in the correspondence and the last two options by performing charge conjugation for quarks in the first two options.

The anomalous charge is experimentally visible only if the external electromagnetic fields at the two sheets are different. The negative charge of DNA due to the presence of phosphate groups implies that the first sheet carries different em field so that this is indeed the case.

The presence effective em charge depending on the details of DNA sequence means that electromagnetism differentiates between different DNA: s strands and some strands might be more favored dynamically than others. It is interesting to look basic features of DNA from this view point. Vertebral mitochondrial code has full $A \leftrightarrow G$ and $C \leftrightarrow T$ symmetries with respect to the third nucleotide of the codon and for the nuclear code the symmetry is almost exact. In the above scenario A and C *resp.* G and T would have different signs and magnitudes of em charge but they would correspond to different weak isospin states for the third quark so that this symmetry would be mathematically equivalent to the isospin symmetry of strong interactions.

The average gauge potential due to the anomalous charge per length at space-time sheet containing ordinary em field of a straight portion of DNA strand is predicted to be proportional to

$$
\frac{dQ_a}{dl} = [p(A) - p(T)]Q(q_A) + [p(G) - p(C)]Q(q_G)\frac{1}{\Delta L} \ ,
$$

where ΔL corresponds to the length increment corresponding to single nucleotide and $p(X)$ represents the frequency for nucleotide X to appear in the sequence. Hence the strength of the anomalous scalar potential would depend on DNA and vanish for DNA for which A and T *resp.* G and C appear with the same frequency.

Chargaff's second parity rule and the vanishing of net anomalous charge

Chargaff's second parity rule states that the frequencies of nucleotides for single DNA strand satisfy the conditions $p(A) \simeq p(T)$ and $p(C) \simeq p(G)$ (I am grateful for Faramarz Faghihi for mentioning this rule and the related [H1] [I91] to me). This rule holds true in a good approximation. In the recent context the interpretation would be as the vanishing of the net anomalous charge of the DNA strand and thus charge conjugation invariance. Stability of DNA might explain the rule and the poly-A tail in the untranslated mRNA could relate stabilization of DNA and mRNA strands.

Together with $p(A) + p(T) + p(G) + p(C) = 1$ Chargaff's rule implies the conditions

$$
\begin{aligned}
&p(A) + p(C) \simeq 1/2 \ , \quad p(A) + p(G) \simeq 1/2 \ , \\
&p(T) + p(C) \simeq 1/2 \ , \quad p(T) + p(G) \simeq 1/2 \ .
\end{aligned}
\tag{3.7.3}
$$

An interesting empirical finding [I91] is that only some points at the line $p(A) + p(C) \simeq 1/2$ are realized in the case of human genome and that these points are in a good accuracy expressible in terms of Fibonacci numbers resulting as a prediction of optimization problem in which Fibonacci numbers are however put in by hand. $p(A) = p(G) = p(C) = p(T) = 1/4$ results as a limiting case. The poly-A tail of mRNA (not coded by DNA) could reflect to the compensation of this asymmetry for translated mRNA.

The physical interpretation would be as a breaking of isospin symmetry in the sense that isospin up and down states for quarks (A and G *resp.* T and C) do not appear with identical probabilities. This need not have any effect on protein distributions if the asymmetry corresponds to asymmetry for the third nucleotide of the codon having $A \leftrightarrow G$ and $T \leftrightarrow C$ symmetries as almost exact symmetries. This of course if protein distribution is invariant under this symmetry for the first two codons.

The challenge would be to understand the probabilities $p_3(X)$ for the third codon from a physical model for the breaking of isospin symmetry for the third codon in the sense that u and $\overline{u}$ at DNA space-time sheet are more favored than d and $\overline{d}$ or vice versa. There is an obvious analogy with spontaneous breaking of vacuum symmetry.

Are genes and other genetic sub-structures singlets with respect to QCD color?

Genes are defined usually as transcribed portions of DNA. Genes are however accompanied by promoter regions and other regions affecting the transcription so that the definition of what one really means with gene is far from clear. In the recent case gene would be naturally TQC program module and gene in standard sense would only correspond to its sub-module responsible for the translated mRNA output of TQC.

Whatever the definition of gene is, genes as TQC program modules could be dynamical units with respect to color interaction and thus QCD color singlets (QCD color should not be confused with braid color) or equivalently - possess integer valued anomalous em charge.

One can consider two alternative working hypothesis - in a well-defined sense diametrical opposites of each other.

1. The division of the gene into structural sub-units correlates with the separation into color singlets. Thus various structural sub-units of gene (say transcribed part, translated part, intronic portions, etc...) would be color singlets.
2. Also different genetic codes that I have discussed in [K38, K39] could distinguish between different structural sub-units. For this option only gene - understood as TQC unit with un-transcribed regions included - would be color singlet.

Color singletness condition is unavoidable for mRNA and leads to a testable prediction about the length of poly-A tail added to the transcribed mRNA after translation.

1. The condition of integer valued anomalous charge for coding regions

In the case of coding region of gene the condition for integer charge is replaced by the conditions

$$n(A) + n(G)\ \ mod\ \ 3 = 0\ \ , \quad n(C) + n(T)\ \ mod\ \ 3 = 0\ \ . \tag{3.7.4}$$

These conditions are not independent and it suffices to check whether either of them is satisfied. The conditions are consistent with $A \leftrightarrow G$ and $T \leftrightarrow C$ symmetries of the third nucleotide. Note that the contribution of the stop codon (TAA, TGA or TAG) and initiating codon ATG to the A+G count is one unit.

2. General condition for integer valued anomalous charge

The anomalous charge of gene or even that of an appropriate sub-unit of gene is integer valued implies in the general case

$$n(A) - n(T) + n(G) - n(C)\ \ mod\ \ 3 = 0\ \ . \tag{3.7.5}$$

Note that this condition does not assume that gene corresponds to $3n$ nucleotides (as I had accustomed to think). The surprising (to me) finding was that gene and also mRNA coding region of the gene in general fails to satisfy $3n$ rule. This rule is of course by no means requiredonly the regions coding for proteins can be thought of as consisting of DNA triplets.

A possible interpretation is in terms of TGD based model for pre-biotic evolution [K38, K39] according to which genetic code (or 3-code) was formed as a fusion of 2-code and 1-code. 2-code and 1-code could still be present in genome and be associated with non-translated regions of mRNA preceding and following the translated region. The genes of 2-code and coding for RNA would have $2n$ nucleotides and the genes of 1-code could also consist of odd number of nucleotides.

There might be analogy with drawings for a building. These contain both figures providing information about building and text giving meta-level information about how to interpret figures. Figures could correspond to 3-code coding for proteins and text could be written with other codes and give instructions for the transcription and translation processes. Prokaryotic code would contain mostly figures (CDS). In eukaryotic code intronic portions could carry rich amounts of this kind of metalevel information. In the case of mRNA untranslated region preceding $5'$ end could provide similar information.

1. Repeating sequences consisting of n copies of same repeating unit could obey 1-code or 2-code. The simplest building blocks of repeating sequences are AT and CG having vanishing anomalous em charge. TATATA.... and CGCGCG... indeed appear often. Also combinations of CG and AT could repeat: so called mini-satellites are CG rich repeating sequences. Interpretation in terms of 2-code suggests itself.

2. Triplet of the unit ATTCG with integer charge repeats also often: in this case 3-code suggests itself. Telomeres of vertebrates consist of a repeating unit TTAGGG which does not have integer charge: this unit appears also as 8-nucleotide variant which suggests 2-code. Color singletness would require that this unit appears $3n$ times.

3. I have also proposed that intronic regions could obey memetic code [K44] predicting that intronic codon can be represented as a sequence of 21 3-codons (implying 2^{63} 63-codons!). Individual intronic segments need not satisfy this rule, only their union if even that. Direct experimentation with gene bank data show that neither introns nor their union correspond to integer multiples of 63 nor 3 or 2 in general.

3. Color singletness conditions for gene

Gene is usually defined as the sequence of DNA coding for mRNA. mRNA involves also two untranslated regions (UTRs) [I1].

1. The $5'$ end of mRNA contains $5'$ cap (methylated G) and $5'$ untranslated region (UTR). The latter can be several kb long for eukaryotes. Methylated G is not coded by DNA but added so that it does not contribute to A+G-T-C count at DNA level.

2. mRNA continues after the stop codon as $3'$ UTR. Translation assigns to UTR also a poly-A tail (up to several hundreds A: s) not coded by DNA and not contributing to A+G-T-C count in the case of DNA. This region contains also AAUAAA which does not contribute to A+G-T-C count of mRNA.

   One could argue that any amino-acid sequence must allow coding and that one function of UTRs is to guarantee integer valued charge for the part of gene beginning from the initiating codon. Of course, also the non-transcribed regions of DNA not included in the standard definition of gene could take care of this.

4. Color singletness conditions for mRNA

Both poly-A tail and G gap are known to relate to the stabilization of mRNA. The mechanism could be addition of an anomalous charge compensating for the anomalous charge of mRNA to guarantee that second Chargaff's rule is satisfied in a good approximation: this hypothesis is testable.

Second function would be to guarantee color-singletness property. Color singletness would mean that transcribed mRNA + cap G + poly-A tail as a separate unit must be QCD color singlet at DNA space-time sheet. mRNA stability requires the condition

$$n(A) - n(T) + n(G) - n(C) + n_{tail}(A) + 1 \ \ mod \ \ 3 = 0 \tag{3.7.6}$$

to be satisfied. The knowledge of gene would thus predict $n_{tail}(A) \ mod \ 3$. This hypothesis is testable.

5.Chargaff's rule for mRNA

If Chargaff's rule applies also to mRNA strands one obtains one of the following predictions

$$\begin{aligned}
&2\left[n(A)+n_{tail}(A)-n(T)\right]-\left[n(G)+1-n(C)\right]\simeq 0 \ , \\
&-\left[n(A)+n_{tail}(A)-n(T)\right]+2\left[n(G)+1-n(C)\right]\simeq 0 \ , \\
&-2\left[n(A)+n_{tail}(A)-n(T)\right]+\left[n(G)+1-n(C)\right]\simeq 0 \ , \\
&\left[n(A)+n_{tail}(A)-n(T)\right]-2\left[n(G)+1-n(C)\right]\simeq 0 \ .
\end{aligned} \tag{3.7.7}$$

Here $n_{tail}(A)$ includes also AAUAA contributing 3 units to it plus possible other structures appearing in the tail added to the translated mRNA. The presence of poly-A tail which could also compensate for the ordinary negative charge of translated part of mRNA would suggest that A corresponds to u or $\overline{d}$ corresponding to options 1 and 4.

6. Moving genes and repeating elements

Transposons [I49], [J9] are moving or self-copying genes. Moving genes cut from initial position and past to another position of double strand. Copying genes copy themselves first to RNA and them to a full DNA sequence which is then glued to the double strand by cut and paste procedure. They were earlier regarded as mere parasites but now it is known that their transcription is activated under stress situations so that they help DNA to evolve. In TQC picture their function would be to modify TQC hardware. For copying transposons the cutting of DNA strand occurs usually at different points for DNA and cDNA so that "sticky ends" result ("overhang" and its complement) [I46]. Often the overhang has four nucleotides. The copied transposon have ends which are reversed conjugates of each other so that transposons are palindromes as are also DNA hairpins. This is suggestive of the origin of transposons.

In order to avoid boring repetitions let us denote by "satisfy P" for having having integer valued (or even vanishing) Q_a. The predictions are following:

1) The double strand parts associated with the segments of DNA produced by cutting should satisfy P.

2) The cutting of DNA should take place only at positions separated by segments satisfying P.

3) The overhangs should satisfy P.

4) Transposons should satisfy P: their reverse ends certainly satisfy P.

In the example mentioned in [I44] the overhang is $CTAG$ and has vanishing Q_a. The cut site $CCTAGG$ has also vanishing Q_a. It is known [J9] that transposons - repeating regions themselves - tend to attach to the repeating regions of DNA [I12].

1. There are several kinds of repeating regions. 6-10 base pair long sequences can be repeated in untranslated regions up to 10^5 times and whole genes can repeat themselves $50-10^4$ times.

2. Repeats are classified into tandems (say TTAGGG associated with telomeres), interspersed repetitive DNA (nuclear elements), and transposable repeat elements. Interspersed nuclear elements (INEs) are classified LINEs (long), SINEs (short), TLTRs (Transposable elements with Long Terminal Repeats), and DNA transposons themselves.

3. LINEs contain AT rich regions. SINEs known as alus (about 280 bps) contain GC rich regions whereas mariner elements (about 80 bps) are flanked by TA pairs. LTRs have length 300-1000 bps. DNA transposons are flanked with two short inverted repeat sequences flanking the reading frame: "inverted" refers to the palindrome property already mentioned.

AT and CG have vanishing Q_a so that their presence in LINEs and SINEs would make the cutting and pasting easy allowing to understand why transposons favor these regions. Viruses are known to contain long repeating terminal sequences (LTR). One could also check whether DNA decomposes to regions satisfying P and surrounded by repeating sequences which satisfy P separately or as whole as in the case DNA transposons.

7. Tests

Some checks of the color singletness hypothesis were made for human genome [I20].

1. For the coding sequences (CDSs) the strong prediction in general fails as expected (condition would pose restrictions on possible amino-acid contents).

2. Color singletness condition fails for genes defined in terms of translated part of mRNA (with gap and poly-A tail excluded). The un-transcribed regions of DNA involved with the gene expression (promoter region, etc...) could guarantee the color singletness. They could also stabilize DNA by bringing in compensating anomalous charge to guarantee second Chargaff's rule. Different genetic codes could distinguish between the subunits of gene.

3. To test color singletness conditions for mRNA one should know the length of poly-A tail. Unfortunately, I do not have access to this information.

4. The computation of total anomalous charges for a handful of genes, introns, and repeat units for some gene bank examples in the case of human genome indicates that both of them tend to carry net em charge which is largest for $(a,g) \leftrightarrow (\overline{d},\overline{u})$ correspondence. The charge is in the range 5-10 per cent from the charge associated with the phosphates (-2 units per nucleotide). For second option giving negative charge (permute u and d) the anomalous charge is few per cent smaller.

   By Chargaff's law the regions outside genes responsible for the control of gene expression must contain a compensating charge of opposite sign. Kind of spontaneous symmetry breaking of charge conjugation symmetry $A \leftrightarrow T, G \leftrightarrow C$ and analogous to matter antimatter symmetry seems to take place. That control regions and translated regions have opposite densities of anomalous charge might also help in the control gene expression.

5. The poly-A tail of mRNA would carry compensating positive anomalous charge: the RNA-quark assignment could be conjugate to the DNA-quark assignment as suggested by what takes place in transcription. For instance, for the option $A \rightarrow \overline{d}$, the prediction for the length of polytail for $A \rightarrow \overline{d}$ option would be about $n_{tail}/n_{mRNA} \simeq 3p_a(mRNA)$ where $N(mRNa)$ is the number of nucleotides in transcribed mRNA and $p_a(mRNA)$ is the per cent of anomalous charge which is typically 5-10 per cent. For $p_a(mRNA) = 10$ per cent this gives as much as 30 per cent. For $A \rightarrow \overline{u}$ option one has $n_{tail}/n_{mRNA} \simeq 3p_a(mRNA)/2$. In this case also p_a is considerably smaller, typically by a factor of of order 2-3 per cent and even below per cent in some cases. Hence the relative length of tail would around 3-5 per cent. This option is perhaps more since it minimizes anomalous charge and maximizes the effectiveness of charge compensation by poly-A tail.

6. The predictions for transposons and their cut and past process should be easily testable.

Summary of possible symmetries of DNA

The following gives a list of possible symmetries of DNA inspired by the identification of braid color.

1. Color confinement in strong form

The states of quarks and anti-quarks associated with DNA both wormhole wormhole throats of braided (living) DNA strand can be color singlets and have thus integer valued anomalous em charge. The resulting prediction depends on the assignment of quarks and antiquarks to A, T, C, G which in principle should be determined by the minimization of em interaction energy between quark and nucleotide. For instance $2(A-T)-(G-C) \ mod \ 3 = 0$ for a piece of living DNA which could make possible color singletness. As a matter fact, color singletness conditions are equivalent for all possible for braid color assignments. This hypothesis might be weakened. For instance, it could hold true only for braided parts of DNA and this braiding are dynamical. It could also hold for entire braid with both ends included only: in this case it does not pose any conditions on DNA.

Questions: Do all living DNA strands satisfy this rule? Are only the double stranded parts of DNA braided and satisfy the rule. What about loops of hairpins?

2. Matter antimatter asymmetry at quark level

$A \leftrightarrow T$ and $G \leftrightarrow C$ corresponds to charge conjugation at the level of quarks (quark $\leftrightarrow$ antiquark). Chargaff's rules states $A \simeq T$ and $C \simeq G$ for long DNA strands and mean matter-antimatter symmetry in the scale of DNA strand. Double strand as a whole is matter anti-matter symmetric.

Matter-antimatter asymmetry is realized functionally at the level of DNA double strand in the sense that only DNA strand is transcribed. The study of some examples shows that genes defined as transcribed parts of DNA do not satisfy Chargaff's rule. This inspires the hypothesis about the breaking of matter antimatter symmetry. Genes have non-vanishing net $A - T$ and $C - G$ and therefore also net Q_a with sign opposite to that in control regions. Just as the Universe is matter-antimatter asymmetric, also genes would be matter-antimatter asymmetric.

3. Isospin symmetry at quark level

$A \leftrightarrow G$ and $T \leftrightarrow A$ correspond change of anomalous em charge by 1 unit and these operations respect color confinement condition. Local modifications of DNA inducing these changes should be preferred. The identification for the symmetries $A \leftrightarrow G$ and $T \leftrightarrow A$ for the third nucleotide of code is as isospin symmetries. For the vertebrate mitochondrial code the symmetry exact and for nuclear code slightly broken.

4. Matter antimatter asymmetry and isospin symmetries for the first two nucleotides

The first two nucleotides of the codon dictate to a high degree which amino-acid is coded. This inspires the idea that 3-code has emerged as fusion of 1- and 2-codes in some sense. There are two kinds of 2-codons. The codons of type A have fractional em charge and net quark number (consisting of either matter or antimatter at quark level) and are not able to form color singlets. The codons of type B have integer em charge and vanishing quark number (consisting of matter and antimatter) and are able to form color singlets. The 2-codons of type A (resp. B) are related by isospin rotations and there should be some property distinguishing between types A and B. There indeed is: if 2-codon is matter-antimatter symmetric, 1-codon is not and vice versa.

1. For almost all type A codons the amino-acid coded by the codon does not depend on the last nucleotide. There are two exceptions in the case of the nuclear code: (leu, leu, phe, phe) and (ile, ile, ile, met). For human mitochondrial code one has (ile, ile, ile, ile) and thus only one exception to the rule. The breaking of matter-antimatter symmetry for the third nucleotide is thus very small.

2. For codons of type B the 4-columns code always for two doublets in the case of vertebrate mitochondrial code so that for codons with vanishing net quark number the breaking of matter-antimatter symmetry for the third nucleotide is always present.

5. Em stability

Anomalous em charge Q_a vanishes for DNA and perhaps also mRNA strand containing also the G cap and poly-A tail which could compensate for the Q_a of the transcribed region so that

$$2(A - T) - (G - C) \simeq 0$$

or some variant of it holds true. Chargaff's rules for long DNA strands imply the smallness of Q_a.

6. Summary of testable working hypothesis

Following gives a summary of testable working hypothesis related to the isospin symmetry and color singletness. The property of having integer valued/vanishing Q_a is referred to as property P.

1. Gene plus control region and also DNA repeats should have property P. Transcribed and control regions of gene have Q_a with opposite signs.

2. Transposons, repeating regions, the overhangs associated with the cut and paste of transposon, and the DNA strands resulting in cutting should have property P. This could explain why transposons can paste themselves to AT and GC ($Q_a = 0$) rich repeating regions of

DNA. The points at which DNA can be cut should differ by a DNA section having property P. This gives precise predictions for the points at which transposons and pieces of viral DNA can join and could have implications for genetic engineering.

3. If also mRNA is braided, it has property P. This can be only true if the poly-A tail compensates for the non-vanishing Q_a associated with the translated region.

4. Living hairpins should have property P. If only double helix parts of hairpins are braided, the prediction is trivially true by the palindrome property. tRNA or at least parts of it could be braided. Braids could end to the nuclear membrane or mRNA or to the amino-acid attachable to tRNA. For stem regions Q_a is integer valued. The fact that the nucleotide of the anticodon corresponding to the third nucleotide of codon can base pair with several nucleotides of mRNA suggests that $I(nositol)$ can have Q_a opposite to that of A, T, C and U opposite to that of A, G. For 2-anticodon the pairing would be unique. This would give a lot of freedom to achieve property P in weak sense for tRNA. Braid structure for tRNA + amino-acid could be different that for tRNA alone and also in the translation the braid structure could change.

5. Telomeres [I47] are of special interests as far as anomalous em charge is considered. Chromosomes are not copied completely in cell replication, and one function of telomeres is to guarantee that the translated part of genome replicates completely for sufficiently many cell divisions. Telomeres consists of 3-20 kilobases long repetitions of TTAGGG, and there is a 100-300 kilobases long repeating sequence between telomere and the rest of the chromosome. Telomeres can form can also 4-stranded structures. Telomere end contains a hair-pin loop as a single stranded part, which prevents the action of DNA repair enzymes on the chromosome end. Telomerase is a reverse transcriptase enzyme involved with the synthesis of telomeres using RNA strand as a template but since its expression is repressed in many types of human cells, telomere length shortens in each cell replication. In the case of germ cells, stem cells and white blood cells telomerase is expressed and telomere length preserved. Telomere shortening is known to relate to aging related diseases. On the other hand, overactive telomere expression seems to correlate with cancer.

   If telomeres possess braid strands, the compensation of Q_a might provide an additional reason for their presence. If this the case and if telomeres are strict multiples of TTAGGG, the shortening of telomeres generates a non-vanishing Q_a unless something happens for the active part of DNA too. Color singletness condition should however remain true: the disappearance of $3n$ multiples of TTAGGG in each replication is the simplest guess for what might happen. In any case, DNA strands would become unstable in cell replication. Q_a could be reduced by a partial death of DNA in the sense that some portions of braiding disappear. Also this would induce ill functioning of TQC harware perhaps related to aging related diseases. Perhaps evolution has purposefully developed this aging mechanism since eternal life would stop evolution.

6. Also amino-acids could be braided. Q_a could vary and correspond to Q_a for one of the codons coding for it. The amino-acid sequences of catalysts attaching to DNA strand should have opposite Q_a for each codon-amino-acid pair so that amino-acid would attach only to the codons coding for it. The TGD based model for nerve pulse [K79] inspires the proposal that magnetic flux tubes connecting microtubules to the axonal membrane allow TQC during nerve pulse propagation when axonal membrane makes transition from gel like phase to liquid crystal phase. Amino-acids of tubulin dimers would be connected by 3-braids, smallest interesting braid, to groups of 3-lipids in axonal membrane and tubulin dimers would define fundamental TQC modules.

Empirical rules about DNA and mRNA supporting the symmetry breaking picture

Somewhat surprisingly, basic facts which can be found from Wikipedia, support the proposed vision about symmetry breaking although, the mechanism of matter antimatter symmetry breaking is more complex than the first guess. I am grateful for Dale Trenary for references which made possible to realize this. Before continuing some comments about the physical picture are in order.

1. The vanishing of the induced Kähler field means that the space-time sheet of DNA is a highly unstable vacuum extremal. The non-vanishing of the induced Kähler electric field is thus a natural correlate for both the stability and the non-vanishing quark number density (matter antimatter asymmetry). The generation of matter antimatter asymmetry induces a net density of anomalous em charge, isospin, and quark number in the portion of DNA considered. This in turn generates not only longitudinal electric field but also a longitudinal Kähler electric field along DNA.

2. Weak electric fields play a key role in living matter. There are electric fields associated with embryos, central nervous system, individual neurons, and microtubules and their direction determines the direction of a process involved (head-to-tail direction, direction of propagation of nerve pulse, ...).

3. Same mechanism is expected to be at work also in the case of DNA and RNA. In the case of gene the direction of transcription could be determined by the direction of the electric field created by gene and telomeres at the ends of chromosomes carrying a net anomalous quark number could be partially responsible for the generation of this field. In the case of mRNA the direction of translation would be determined in the similar manner. The net anomalous em charges of poly-A tail and the transcribed part of mRNA would have opposite signs so that a longitudinal electric field would result.

It will be found that this picture is consistent with empirical findings about properties of DNA.

7. Breaking of matter antimatter symmetry and isospin symmetry for entire genome

Chargaff's rules are not exact and the breaking gives important information about small breakings of isospin and matter-antimatter symmetries at the level of entire genome. The basic parameters are em charge per nucleotide, isospin per nucleotide, the amount of quark number per nucleotide, and the ratio of u and d type matters coded by $(G+C)/(A+T)$ ratio. Recall that there are four options for the map of A, T, C, G to quarks and antiquarks and for option 3) *resp.* 4) the anomalous em charge is opposite to that for 1) *resp.* 2).

Table 3.3 gives A, T, C, G contents (these data are from Wikipedia [I7]) provides interesting data about DNA It will be found that so called Szybalski's rules can be interpreted as saying that for coding regions there is breaking of the approximate matter antimatter asymmetry.

Note that matter antimatter asymmetry in the scale of entire genome has largest positive value for human genome and negative value only for yeast genome: this case the magnitude of the asymmetry is largest.

For option 2) the amount of anomalous charge is about.0057e per nucleotide and thus about $3 \times 10^7 e$ for entire human DNA having length of about 1.8 meters. The inspection of tables of [I47] shows that the anomalous em charge for the repeating sequence defining the telomere is always non-vanishing and has always the same sign. Telomeres for human chromosomes consist of TTAGGG repetitions with anomalous em charge with magnitude $5e/3$ for all options and have a length measured in few kbases. Human genome as has 24 chromosomes so that the total anomalous em charge of telomeres is roughly $24 \times (5/18) \times x10^3 e \sim .8 \times 10^3 xe$, $1 < x < 10$. The anomalous em charge of telomeres is three orders of magnitude smaller than that of entire DNA but if DNA is quantum critical system the change the total anomalous em charge and quark number due to the shortening of telomeres could induce instabilities of DNA (due to the approach to vacuum extremal) contributing to aging. Note that the small net value of quark number in all the cases considered might be necessary for overall stability of DNA. Telomeres are also known to prevent the ends of chromosomes to stick to each other. This could be partially due to the Coulomb repulsion due to the anomalous em charge.

According to [I7] Chargaff's rules do not apply to viral organellar genomes (mitochondria [I31], plastids) or single stranded viral DNA and RNA genomes. Thus approximate matter antimatter symmetry fails for DNA: s of organelles involved with metabolism. This might relate to the fact that the coding portion of DNA is very high and repeats are absent. Chargaff's rule applies not only to nucleotides but also for oligonucleotides which corresponds to DNA or RNA sequences with not more than 20 bases. This means that for single strand oligonucleotides and their conjugates appear in pairs. Matter antimatter asymmetry would be realized as presence

	Human	Chicken	Grass− hopper	Sea Urchin	Wheat	Yeast	E.Coli
$p(A)$	0.3090	0.2880	0.2930	0.3280	0.2730	0.3130	0.2470
$p(T)$	0.2940	0.2920	0.2930	0.3210	0.2710	0.3290	0.2360
$p(C)$	0.1990	0.2050	0.2050	0.1770	0.2270	0.1870	0.2600
$p(G)$	0.1980	0.2170	0.2070	0.1730	0.2280	0.1710	0.2570
$\frac{dq_1}{dn}$	0.0103	−0.0067	−0.0007	0.0060	0.0010	−0.0053	0.0083
$\frac{dq_2}{dn}$	0.0057	−0.0093	−0.0013	0.0050	−0.0000	0.0053	0.0057
$\frac{dI_3}{dn}$	0.0080	−0.0080	−0.0010	0.0055	0.0005	0.0000	0.0070
$\frac{d(q-\overline{q})}{dn}$	0.0140	0.0080	0.0020	0.0030	0.0030	−0.0320	0.0080
$\frac{p(A+T)}{p(G+C)}$	1.5189	1.3744	1.4223	1.8543	1.1956	1.7933	0.9342

(3.7.8)

Table 3.3: The table gives A, T, C, G contents (these data are from Wikipedia [I7]), the amount of quark charge per nucleotide for the options 1) *resp.* 2) given by $dq_1/dn = p[2(A-T)-G-C)]/3$ *resp.* $dq_2/dn = p[A-T-2(G-C)]/3$, the amount $dI_3/dn = p(A-G+C-T]/2$ of isospin per nucleotide, the amount $d(q-\overline{q})/dn = p(A-T+G-C)$ of quark number per nucleotide, and $(A+T)/(C+G)$ ratio for *entire genomes* in some cases.

of matter blobs and their conjugates. This might relate to the mechanism how the sequences of oligonucleotides are generated from DNA and its conjugate.

8. Breaking of matter antimatter symmetry for coding regions

As noticed, one can consider three type of symmetry breaking parameters for DNA in DNA as TQC model. There are indeed three empirical parameters of this kind. Chargaff rules have been already discussed and correspond to approximate matter antimatter symmetry. The second asymmetry parameter would measure the asymmetry between $u\overline{u}$ and $d\overline{d}$ type matter. $p(G+C)$ corresponds to the fraction of $d\overline{d}$ type quark matter for option 1) and $u\overline{u}$ matter for option 2). It is known that G+C fraction $p(G+C)$ characterizes genes [I77] and the value of $p(G+C)$ is proportional to the length of the coding sequence [I23, I77].

Besides Chargaff rules holding true for entire genome also Szybalski's rules [I7] hold true but only for coding coding regions. The biological basis of neither rules is not understood. The interpretation of Chargaff's rules would be in terms of approximate matter antimatter symmetry and the vanishing of net isospin at the level of quarks whereas Szybalski's rule would state the breaking of these symmetries non-coding regions. Hence all the three basic empirical rules would have a nice interpretation in DNA as TQC picture.

Consider now Szybalski's rules in more detail.

1. In most bacterial genomes (which are generally 80-90 % coding) genes are arranged in such a fashion that approximately 50 % of the coding sequence lies on either strand. Note that either strand can act as a template (this came as a surprise for me). Szybalski, in the 1960s, showed that in bacteriophage coding sequences purines (A and G) exceed pyrimidines (C and T). This rule has since been confirmed in other organisms and known as Szybalski's rule [I7, I78]. While Szybalski's rule generally holds, exceptions are known to exist.

   Interpretation. A breaking of matter antimatter symmetry occurs in coding regions such that the net breakings are opposite for regions using different templates and thus different directions of transcription (promoter to the right/left of coding region).

2. One can actually characterize Szybalski's rules more precisely. By Chargaff's rules one has $p(A+T) \simeq 1-p(G+C))$. In coding regions with low value of $p(G+C)$ $p(A)$ is known to be higher than on the average whereas for high value of $p(G+C)$ $p(G)$ tends to higher than on the average.

Interpretation. These data do not fix completely the pattern of breaking of the approximate matter antimatter symmetry.

i) It could take place for both kinds of quark matter ($u\overline{u}$ and $d\overline{d}$): both $p(A)$ and $p(G)$ would increase from its value for entire genome but the dominance of A over G or vice versa would explain the observation.

ii) The breaking could also occur only for the dominating type of quark matter ($u\overline{u}$ or $d\overline{d}$) in which case only $p(A)$ or $p(G)$ would increase from the value for entire genome.

Also a net isospin is generated which is of opposite sign for short and long coding sequences so that there must be some critical length of the coding sequences for which isospin per nucleotide vanishes. This length should have biological meaning.

3. For mRNA $A+G$ content is always high. This is possible only because the template part of the DNA which need not be always the same strand varies so that if it is strand it has higher $A+G$ content and if it is conjugate strand it has higher $T+C$ content.

Interpretation. mRNA breaks always matter antimatter symmetry and the sign of matter antimatter asymmetry is always the same. Thus mRNA is analogous to matter in observed universe. The poly-A tail added to the end of mRNA after transcription to stabilize it would reduce the too large values of isospin and anomalous em charge per nucleon due to the fact that mRNA does not contain regions satisfying Chargaff's rules. It would also generate the needed longitudinal electric field determining the direction of translation. In the case of DNA the breaking of matter antimatter symmetry is realized at the functional level by a varying direction of transcription and variation of template strand so that matter antimatter symmetry for the entire DNA is only slightly broken. Direction of transcription would be determined by the direction of the electric field. The stability of long DNA sequences might require approximate matter antimatter symmetry for single DNA strand if it is long. In the case of simple genomes (mitochondrial, plastid, and viral) the small size of the genome, the high fraction of coding regions, and the absence of repeating sequences might make approximate matter antimatter symmetry un-necessary. An interesting working hypothesis is that the direction of transcription is always the same for these genomes.

One can try to use this information to fix the most probable option for nucleotide quark correspondence.

1. In nuclear physics the neutron to proton ratio of nucleus increases as nucleus becomes heavier so that the nuclear isospin becomes negative: $I_3 < 0$. The increase of the nuclear mass corresponds to the increase for the length of the coding region. Since G/A fraction increases with the length of coding region, G should correspond to either d quark (($Q_a < 0, I_3 = -1/2$)) or its charge conjugate d_c ($Q_a < 0$). Hence option 1) or its charge conjugate would be favored.

2. If one takes very seriously the analogy with cosmic matter antimatter asymmetry then matter should dominate and only $(A, G, T, C) \rightarrow (u, d, \overline{u}, \overline{d})$ option would remain.

Szybalski's findings leave open the question whether non-coding regions obey the Chargaff rules in good approximation or whether also they appear as pairs with opposite matter antimatter asymmetry. Introns are belong to coding regions in the sense that they are transcribed to mRNA. Splicing however cuts them off from mRNA. It is not clear whether introns break the approximate matter antimatter symmetry or not. If breaking takes place it might mean that introns code for something but not chemically. On the other hand, the absence of asymmetry might serve at least partially as a signal telling that introns must be cut off before translation. Many interesting questions represent itself. For instance, how the symmetry breaking parameters, in particular matter antimatter asymmetry parameter, depend on genes. The correlation with gene length is the most plausible guess.

Genetic codes and TQC

TGD suggests the existence of several genetic codes besides 3-codon code [K45, **?**]. The experience from ordinary computers and the fact that genes in general do not correspond to $3n$ nucleotides encourages to take this idea more seriously. The use of different codes would allow to tell what kind of information a given piece of DNA strand represents. DNA strand would be like a drawing of building containing figures (3-code) and various kinds of text (other codes). A simple drawing for the building would become a complex manual containing mostly text as the evolution proceeds: for humans 96 per cent of code would corresponds to introns perhaps obeying some other code.

The hierarchy of genetic codes is obtained by starting from n basic statements and going to the meta level by forming all possible statements about them (higher order logics) and throwing away one which is not physically realizable (it would correspond to empty set in the set theoretic realization). This allows $2^n - 1$ statements and one can select 2^{n-1} statements consistent with a given atomic statement (1 bit fixed) (half of the full set of statements) and say that these are true and give kind of axiomatics about world. The remaining statements are false. DNA would realize only these statements.

The hierarchy of Mersenne primes $M_n = 2^n - 1$ with $M_{n(next)} = M_{M_n}$ starting from $n = 2$ with $M_2 = 3$ gives rise to 1-code with 4 codons, 3-code with 64 codons, and $3 \times 21 = 63$-code with 2^{126} codons [K45] realized as sequences of 63 nucleotides (the length of 63-codon is about $2L(151)$, roughly twice the cell membrane thickness. It is not known whether this Combinatorial Hierarchy continues ad infinitum. Hilbert conjectured that this is the case.

In the model of pre-biotic evolution also 2-codons appear and 3-code is formed as the fusion of 1- and 2-codes. The problem is that 2-code is not predicted by the basic Combinatorial Hierarchy associated with $n = 2$.

There are however also other Mersenne hierarchies and the next hierarchy allows the realization of the 2-code. This Combinatorial Hierarchy begins from Fermat prime $n = 2^k + 1 = 5$ with $M_5 = 2^5 - 1 = 31$ gives rise to a code with 16 codons realized as 2-codons (2 nucleotides). Second level corresponds to Mersenne prime $M_{31} = 2^{31} - 1$ and a code with $2^{30=15\times 2}$ codons realized by sequences of 15 3-codons containing 45 nucleotides. This corresponds to DNA length of 15 nm, or length scale $3L(149)$, where $L(149) = 5$ nm defines the thickness of the lipid layer of cell membrane. $L(151) = 10$ nm corresponds to 3 full 2π twists for DNA double strand. The model for 3-code as fusion of 1- and 2-codes suggests that also this hierarchy - which probably does not continue further - is realized.

There are also further short Combinatorial hierarchies corresponding to Mersenne primes [A3].

1. $n = 13$ defines Mersenne prime M_{13}. The code would have $2^{12=6\times 2}$ codons representable as sequences of 6 nucleotides or 2 3-codons. This code might be associated with microtubuli.

2. The Fermat prime $17 = 2^4 + 1$ defines Mersenne prime M_{17} and the code would have $2^{16=8\times 2}$ codons representable as sequences of 8 nucleotides.

3. $n = 19$ defines Mersenne prime M_{19} and code would have $2^{18=9\times 2}$ codons representable as sequences of 9 nucleotides or three DNA codons.

4. The next Mersennes are M_{31} belonging to $n = 5$ hierarchy, M_{61} with $2^{60=30\times 2}$ codons represented by 30-codons. This corresponds to DNA length $L(151) = 10$ nm (cell membrane thickness). M_{89} (44-codons), M_{107} (53-codons) and M_{127} (belonging to the basic hierarchy) are the next Mersennes. Next Mersenne corresponds to M_{521} (260-codon) and to completely super-astrophysical p-adic length scale and might not be present in the hierarchy.

   This hierarchy is realized at the level of elementary particle physics and might appear also at the level of DNA. The 1-, 2-, 3-, 6-, 8-, and 9-codons would define lowest Combinatorial Hierarchies.

3.8 Cell Replication And TQC

DNA as TQC model leads to quite detailed ideas about the evolution of the genetic code and the mechanisms of bio-catalysis and of protein folding [K38, K39]. These applications in turn leads to a considerable generalization of DNA as TQC concept [K38, K39] . The presence of braiding leads also to a revision of the model of nerve pulse and EEG [K79, K33]. Here the discussion is restricted to one particular example. One can look what happens in the cell replication in the hope of developing more concrete ideas about TQC in multicellular system. This process must mean a replication of the braid's strand system and a model for this process gives concrete ideas about how multicellular system performs TQC.

3.8.1 Mitosis And TQC

Mitosis is the form of cell replication yielding soma cells and it is interesting what constraints this process gives on TQC and whether the special features of this process could be understood from computational point of view.

1. During mitosis chromosomes [I32] are replicated. During this process the strands connecting chromosomes become visible: the pattern brings in mind flux tubes of magnetic field. For prokaryotes the replication of chromosomes is followed by the fission of the cell membrane. Also plant nuclei separated by cellulose walls suffer fission after the replication of chromosomes. For animals nuclear membranes break down before the replication suggesting that nuclear TQC programs are reset and newly formed nuclei start TQC from a clean table. For eukaryotes cell division is controlled by centrosomes [I6]. The presence of centrosomes is not necessary for the survival of the cell or its replication but is necessary for the survival of multicellular. This conforms with the proposed picture.

2. If the conjugate strands are specialized in TQC, the formation of new double strands does not involve braids in an essential manner. The formation of conjugate strand should lead to also to a generation of braid strands unless they already exist as strands connecting DNA and its conjugate and are responsible for "printing". These strands need not be short. The braiding associated with printing would be hardware program which could be genetically determined or at least inherited as such so that the strands should be restricted inside the inner cell membrane or at most traverse the inner nuclear membrane and turn back in the volume between inner membrane and endoplasmic reticulum.

   The return would be most naturally from the opposite side of nuclear membrane which suggest a breaking of rotational symmetry to axial symmetry. The presence of centriole implies this kind of symmetry breaking: in neurons this breaking becomes especially obvious. The outgoing braid strands would be analogous to axon and returning braid strands to dendrites. Inner nuclear membrane would decompose the braiding to three parts: one for strand, second for conjugate strand, and a part in the empty space inside nuclear envelope.

3. The formation of new DNA strands requires recognition relying on "strand color" telling which nucleotide can condense at it. The process would conserve the braidings connecting DNA to the external world. The braidings associated with the daughter nuclei would be generated from the braiding between DNA and its conjugate. As printing software they should be identical so that the braiding connecting DNA double strands should be a product of a braiding and its inverse. This would however mean that the braiding is trivial. The division of the braid to three parts hinders the transformation to a trivial braid if the braids combine to form longer braids only during the "printing" activity.

4. The new conjugate strands are formed from the old strands associated with printing. In the case of plants the nuclear envelope does not disintegrate and splits only after the replication of chromosomes. This would suggest that plant cells separated by cell walls perform only intracellular TQC. Hermits do not need social skills. In the case of animals nuclear envelope disintegrates. This is as it must be since the process splits the braids connecting strand and conjugate strands so that they can connect to the cell membrane. The printing braids are inherited as such which conforms with the interpretation as a fixed software.

5. The braids connecting mother and daughter cells to extranuclear world would be different and TQC braidings would give to the cell a memory about its life-cycle. The age ordering of cells would have the architecture of a tree defined by the sequence of cell replications and the life history of the organism. The 4-D body would contain kind of log file about TQC performed during life time: kind of fundamental body memory.

6. Quite generally, the evolution of TQC programs means giving up the dogma of genetic determinism. The evolution of TQC programs during life cycle and the fact that half of them is inherited means kind of quantum Lamarckism [I24]. This inherited wisdom at DNA level might partly explain why we differ so dramatically from our cousins.

3.8.2 Sexual Reproduction And TQC

Meiosis [I28] produces gametes in which the pair of chromosomes from parents is replaced with single chromosome obtained as chimera of the chromosomes of parents. Meiosis is the basic step of sexual reproduction and it is interesting to study it from TQC point of view.

1. Sexual reproduction of eukaryotes relies on haploid cells differing from diploid cells in that chromatids do not possess sister chromatids. Whereas mitosis produces from single diploid [I40] cell two diploid cells, meiosis gives rise to 4 haploid [I40] cells. The first stage is very much like mitosis. DNA and chromosomes duplicate but cell remains a diploid in the sense that there is only single centrosome: in mitosis also centrosome duplicates. After this the cell membrane divides into two. At the next step the chromosomes in daughter cells split into two sister chromosomes each going into its own cell. The outcome is four haploid cells.

2. The presence of only single chromatid [I8] in haploids means that germ cells would perform only one half of the "social" TQC performed by soma cells [I45] who must spend their life cycle as a member of cell community. In some cells the TQC would be performed by chromatids of both father and mother making perhaps possible kind of stereo view about world and a model for couple - the simplest possible social structure.

3. This brings in mind the sensory rivalry between left and right brain: could it be that the two TQC's give competing computational views about world and how to act in it? We would have inside us our parents and their experiences as a pair of chromatids representing chemical chimeras of chromatid pairs possessed by the parents: as a hardware - one might say. Our parents would have the same mixture in software via sharing and fusion of chromatid mental images or via quantum computational rivalry. What is in software becomes hardware in the next generation.¡/p¿¡p¿

4. The ability of sexual reproduction to generate something new relates to meiosis. During meiosis genetic recombination [I19] occurs via chromosomal crossover which in string model picture would mean splitting of chromatids and the recombination of pieces in a new manner $(A_1 + B_1) + (A_2 + B_2) \rightarrow (A_1 + B_2) + (A_2 + B_1)$ takes place in crossover and $(A_1 + B_1 + C_1) + (A_2 + B_2 + C_2) \rightarrow (A_1 + B_2 + C_1) + (A_2 + B_1 + C_2)$ in double crossover. New hardware for TQC would result by combining pieces of existing hardware. What this means in terms of braids should be clarified.

5. Fertilization is in well-define sense the inverse of meiosis. In fertilization the chromatids of spermatozoa and ova combine to form the chromatids of diploid cell. The recombination of genetic programs during meiosis becomes visible in the resulting TQC programs.

3.8.3 What Is The Role Of Centrosomes And Basal Bodies?

Centrosomes [I6] and basal bodies [I3] form the main part of Microtubule Organizing Center [I30]. They are somewhat mysterious objects and at first do not seem to fit to the proposed picture in an obvious manner.

1. Centrosomes consist two centrioles [I5] forming a T shaped antenna like structure in the center of cell. Also basal bodies consist of two centrioles but are associated with the cell membrane. Centrioles and basal bodies have cylindrical geometry consisting of nine triplets of microtubules along the wall of cylinder. Centrosome is associated with nuclear membrane during mitosis.

2. The function of basal bodies which have evolved from centrosomes seems to be the motor control (both cilia [I9] and flagella [I17]) and sensory perception (cilia). Cell uses flagella and cilia to move and perceive. Flagella and cilia are cylindrical structures associated with the basal bodies. The core of both structures is axoneme having $9 \times 2 + 2$ microtubular structure. So called primary cilia do not posses the central doublet and the possible interpretation is that the inner doublet is involved with the motor control of cilia. Microtubules [I29] of the pairs are partially fused together.

3. Centrosomes are involved with the control of [I32] [I32]. Mitosis can take place also without them but the organism consisting of this kind of cells does not survive. Hence the presence of centrosomes might control the proper formation of TQC programs. The polymerization of microtubules [I29] is nucleated at microtubule self-organizing center which can be centriole or basal body. One can say that microtubules which are highly dynamical structures whose length is changing all the time have their second end anchored to the self-organizing center. Since this function is essential during mitosis it is natural that centrosome controls it.

4. The key to the understanding of the role of centrosomes and basal bodies comes from a paradox. DNA and corresponding TQC programs cannot be active during mitosis. What does then control mitosis?

   (a) Perhaps centrosome and corresponding TQC program represents the analog of the minimum seed program in computer allowing to generate an operating system like Windows 2000 (the files from CD containing operating system must be read!). The braid strands going through the microtubules of centrosome might define the corresponding TQC program. The isolation from environment by the microtubular surface might be essential for keeping the braidings defining these programs strictly unchanged.

   (b) The RNA defining the genome of centrosome (yes: centrosome has its own genome defined by RNA rather than DNA [I6] !) would define the hardware for this TQC. The basal bodies could be interpreted as a minimal sensory-motor system needed during mitosis.

   (c) As a matter fact, centrosome and basal bodies could be seen as very important remnants of RNA era believed by many biologists to have preceded DNA era. This assumption is also made in TGD inspired model of prebiotic evolution [K38, K39].

   (d) Also other cellular organelles possessing own DNA and own TQC could remain partly functional during mitosis. In particular, mitochondria are necessary for satisfying energy needs during the period when DNA is unable to control the situation so that they must have some minimum amount of own genome.

5. Neurons [I33] do not possess centrosome which explains why they cannot replicate. The centrioles are replaced with long microtubules associated with axons and dendrites. The system consisting of microtubules corresponds to a sensory-motor system controlled by the TQC programs having as a hardware the RNA of centrosomes and basal bodies. Also this system would have a multicellular part.

6. Intermediate filaments [I21], actin filaments [I2], and microtubules [I29] are the basic building elements of the eukaryotic cytoskeleton [I11]. Microtubules, which are hollow cylinders with outer radius of 24 nm, are especially attractive candidates for structures carrying bundles of braid strands inside them. The microtubular outer-surfaces could be involved with signalling besides other well-established functions. It would seem that microtubules cannot be assigned with TQC associated with nuclear DNA but with RNA of centrosomes and could contain corresponding braid strand bundles. It is easy to make a rough estimate for the number of strands and this would give an estimate for the amount of RNA associated with centrosomes. Also intermediate filaments and actin filaments might relate to cellular organelles having their own DNA.

3.9 Indirect Evidence For The DNA As Topological Quantum Computer Model

There is a profound revolution taking place in genetics [I75]. It is fair to say that genetic determinism is falling down and the revolution that is waiting just around the corner will be more profound that anything that has taken place before this in biology. The term "genome's dark matter" expresses what has been discovered during last years. The motivation for the term is the strong analogy with the dark matter of physics. In TGD framework this analogy might be much more than analogy.

The basic anomalies discussed in the article are following.

1. Trans-generational inheritance [I76, I83]. The stretches of DNA which were present in parent's or grand parents' genome but are not present in the genome of offspring affect the traits of offspring.
2. Context sensitivity of gene's effect: the effect of gene is highly sensitive on its environment in DNA.
3. Genes explain in many cases only 10 percent of the disease's inheritability: this is "missing heritability" problem [I62].

It is interesting to try to interpret these results in the framework provided by the model of DNA as topological quantum computer. It is good to summarize the basic ideas and concepts behind the model.

3.9.1 The Notion Of Magnetic Body

The notion of magnetic body as intentional agent using biological body as a motor instrument and sensory receptor with communications taking place in terms of fractal generalization of EEG is the key idea. Each physical system consisting of matter has magnetic body. Magnetic body of given living organism has a fractal onion like structure with layer sizes varying from sub-cellular scales to the scales assignable to EEG frequencies (Earth size) and even above up to the scale of light-life and maybe beyond to scales characterizing the evolution of species.

Immediate implications are the notion of collective DNA expression made possible by the interaction of DNA strands so that they belong to magnetic flux sheets: in this manner not only DNAs of cells and organelles, organs, single organism but also groups of organisms can form coherent structures expressing themselves in synchronous manner. This is a testable prediction.

3.9.2 DNA As Topological Quantum Computer

Topological quantum computation is based on braiding: various braiding patterns for braid strands define the TQC programs. There are two types of braids: time-like and space-like.

1. Cell membrane is 2-D liquid and the flow of lipids affected by the flow of cellular liquid and also by nerve pulse patterns in case of neurons induce braiding. This braiding takes place dynamically at the 2-D parquette defined by the cell membrane in time direction and dance metaphor applies to it. Running TQC program can be seen as dancing.
2. The magnetic flux tubes connecting DNA nucleotides to the lipids of nuclear membrane and cell membrane and possibly also to membranes of other cells define the space-like braid strands. Since the flux tubes connected to DNA strands are like threads connecting the feet of dancers to the walls of the dance hall the resulting space-like braiding codes TQC program to memory, which is highly robust as a topological invariant.

There is a kind of duality between time-like and space-like braidings. This is a new element to the conventional quantum computation paradigm. Combined with the idea that memories are stored in geometric past in zero energy ontology this gives an extremely elegant memory storage mechanism.

3.9.3 Implications For Genetics

This vision has profound implications for genetics.

1. Genes define only the hardware of TQC. Software is defined by the braidings. Introns whose portion steadily increases as the evolutionary level becomes higher and is more than 95 per cent in humans, have been traditionally interpreted as junk DNA. In this framework introns

correspond naturally to that part of genome specialized in TQC: from the point of view of TQC it does matter much whether the intronic portions correspond to repeating sequences (interpreted as a signal for "junkness") or not.

2. The evolution of topological quantum computation programs would be far more important than the evolution of genome and the huge differences between species with almost the same genome (such as we and our cousins) could be understood in terms ofw hat at our level of hierarchy corresponds to cultural evolution due to the evolution of topological quantum computer programs. The evolution would have been for a long time evolution of TQC programs rather than that of hardware as the fact that the size of genome and details of does not matter much suggests. The appearance of of prokaryotes (and multi-cellulars) meant the emergence of introns and perhaps also the precedessor of cultural evolution as the evolution of quantum software and collective magnetic bodies.

3.9.4 Implications For Mendelian Anomalies

This vision also suggests how to understand the origin of the Mendelian anomalies.

1. Trans-generational inheritance might be understood as an inheritance of TQC programs carrying indirectly information also about the genome of parents. If one accepts TGD vision about organisms as 4-D structures, one must of course be ready to even ask whether genetic effects could be also take place via the mediation of the magnetic bodies assignable to structures formed by several generations.

   Of course, it is far from clear what the mechanism leading to the inheritance of TQC programs could mean. Does it make sense to speak about magnetic body for causal diamonds (CDs) in time scale of several generations? Could TQC programs associated with the magnetic bodies affect also the future generations by signals realized in terms of positive and negative energy photons propagating in opposite time directions? In zero energy ontology (ZEO) instantaneous communications realized as time reflections are indeed possible and are central in the realization of memories and anticipation in TGD Universe.

2. The context sensitivity of the effect of particular gene could be understood in this picture since the programs are determined not only by a single gene but longer portions of DNA. Individual genes do not matter much when one tries to understand genetic correlates for autism, schizophrenia, and other complex diseases related to functions rather than mere structure. If one speaks about structure, such as the color of flowers situation is of course very simple and Mendelian approach works well. An interesting question is how closely the structure-function dichotomy, exon-intron dichotomy and hardware-software dichotomy correspond to each other.

3. High level diseases would be much more programming errors than hardware problems. This would solve "missing heritability" problem.

What is amusing, that the physicist's dark matter would be behind "genome's dark matter": magnetic flux tubes are assumed to be carriers of dark matter- dark quarks in fact. In the proposed model quarks with large Planck constant meaning that their Compton length scales is scaled up and gives them size scale of order cell at least are in key role!

3.10 How To Build A Quantum Computer From Magnetic Flux Tubes

Magnetic flux tubes play a key role in TGD inspired model of quantum biology. Could the networks of magnetic flux tubes containing dark particles with large $\hbar$ in macroscopic quantum states and carrying beams of dark photons define analogs of electric circuits? This would be rather cheap technology since no metal would be needed for wires. Dark photon beams would propagate along the flux tubes representing the analogs of optical cables and make possible communications with maximal signal velocity.

I have actually made much more radical proposal in TGD inspired quantum biology. According to this proposal, flux tube connections are dynamical and can be changed by reconnection of two magnetic flux tubes. The signal pathways $A \to C$ and $B \to D$ would be transformed to signal pathways to $A \to D$ and $B \to C$ by reconnection. Reconnection actually represents a basic stringy vertex. The contraction of magnetic flux tubes by a phase transition changing Planck constant could be fundamental in bio-catalysis since it would allow distant molecules connected by flux tubes to find each other in the molecular crowd.

DNA as a topological quantum computer is the idea that I have been developing for 5 years or so. I have concentrated on the new physics realization of braids and devoted not much thought to how the quantum computer problems might run in this framework. I was surprised to realize how little I know about what happens in even ordinary computation. Instead of going immediately to Wikipedia I take the risk of publicly making myself fool and try to use my own brain.

3.10.1 What Can One Learn From Ordinary Computer Programs

One could begin with the question what happens in classical computation. How the program is realized and how it runs? The notion of Turing machine (see `http://tinyurl.com/7c4kl`) represents an extreme abstraction mentioning nothing about the technical side and does not help much in attempts to answer these questions. Turing paradigm also assumes that program is a temporal sequence of operations. These operations could however correspond to a linear spatial sequences and inputs and outputs in this case would correspond to boundary values at the ends of the linear structure. This requires that the dynamics is such that evolution in spatial direction is analogous to a deterministic time evolution. In this case it is much easier to imagine biological realizations of quantum computer programs in TGD inspired bio-world.

To develop concrete ideas, one can start from the picture provided by ordinary computer program.

1. Programs consist of temporal/spatial sequences of commands and commands represent basic functions from which one can build more complex functions by the composition of functions having some numbers of input and output arguments. The eventual output variable can be expressed by printing of a piece of text or as an image in the computer screen. Each step in the program corresponds to a composition of functions: $f_{n+1} = g_{n+1} \circ f_n$. There is some minimal set of primitive/prime functions from which one builds up more complex functions by composition.

2. How this is realized at the level of hardware? One can assume that the basic functions are at some fixed places in the computer memory having addresses given by integers represented as bit sequences. This address represents the command - a name of the function. The names for input variables and output variables are bit sequences giving the addresses of the places containing the values of these variables. Program is a sequence of commands represented as bit sequences giving the address of the function to be computed at a given step and the addresses of inputs and outputs. As the processing unit reads the command, it generates/activates connections from the addresses of inputs to the address representing the function and from this address to the addresses of outputs.

   Essentially the challenge is to reconnect, build/activate connections. An interesting question is whether learning identified as strengthening of synaptic connections (see `http://tinyurl.com/cn7724o`) [J2] is one particular example of this process.

3. How the sequence of bits representing command address is realized? As the processing unit reads the address of command it should automatically create/activate a connection from this address to the command address. The connections from the processing unit to the addresses could exist physically as wirings.

4. It is not necessary that program is dynamical so that the inputs and outputs would be initial and final values of variables. Inputs and outputs could also correspond to values of variables at the ends of a linear structure. In topological quantum computation space-like entanglement would represent superposition of input-output pairs characterizing a function as a rule with instances represented as instances appearing in the superposition.

If this picture is roughly correct, re-connection would be the basic process. Reconnection is the basic process for magnetic flux tubes and ADP$\leftrightarrow$ ATP has been assigned to this process with ATP molecule serving as a relay activating the flux tube connection. Maybe ADP-ATP process, which is usually seen as a basic step of metabolism, could be seen as the core step for quantum computation performed by living matter. One expects that the presence ATP makes the rule represented by negentropic quantum entanglement conscious.

3.10.2 Quantum Computation Magnetic Flux Tubes As Connections

Consider now quantum computation could take place in a circuitry having magnetic flux tubes as wires and some bio-molecules of groups of them as units defining prime functions. DNA as topological quantum computer could be taken as a starting point. The outcome of quantum computation is determined statistically as ensemble average so that a large number of copies of the program should be present and realized in terms of groups of cells or molecules connected by braidings if the quantum computation is space-like. This option seems more natural than time-like quantum computation realized as a 2-D liquid flow of lipids in the lipid layers of the cell membrane.

The hardware

Consider first the hardware of topological quantum computation using space-like braids.

1. Magnetic flux tubes would represent the wires along which inputs and outputs travel in the case of classical computation or dynamical quantum computation. In the case of space-like topological quantum computation entanglement is between the ends of the flux tubes.

2. Variables could be represented in many ways. For space-like quantum computations they could correspond to spin states of dark electrons at flux tubes or to polarization states of dark electrons at the flux tubes. In the original model of DNA as topological quantum computer quarks and antiquarks where proposed as a representation of genetic codons: also this quite science fictive option could make sense in TGD Universe since TGD predicts scaled versions of QCD like dynamics and presence of elementary particles in several p-adic scales and in scales dictated by value of Planck constant for given p-adic length scale.

   The spin states of electron pair has been proposed as one possible representation of the 4 genetic codons. Quantum variables would be represented by qubit sequences and the measurement of qubit would give a bit sequence characterizing the classical value of the variable. Bio-molecules would be natural places for storing the values of the variables. For dynamical computations the values of variables could be transmitted using dark photons.

3. There would exist basic processing units calculating the prime functions from which more complex functions would be obtained as composites. Basic units could correspond to bio-molecules. In the case of classical computation the inputs to molecules and outputs from them would travel along the flux tubes. In quantum computation these signals could be used to control the initial values of the variables. Molecules could also serve as gates for quantum computation.

Representation of programs

The basic program units in the case of quantum computation would be represented by braidings.

1. If the ends of braid strands are able to move freely when needed, it becomes possible to re-write programs. Lipid layers of cell membrane can be in liquid crystal state so that these are ideal for this purpose. The time-like braiding resulting from lipid flow and representing running topological quantum computation program would induce space-like braiding representing space-like topological quantum computation or a rule. A particular quantum computer program represented as space-like braiding of the flux tubes would result as liquid crystal melts for a moment and freezes again.

   The process (see `http://tinyurl.com/yarrblxn`) in which proteins covered by ordered water analogous to ice temporarily melt and form aggregates [I43] is basic process induced by the feed of energy to the cellular system and could be compared to cellular summer. This process could mean quite generally molecular re-programming induced by the flow of cellular water inducing molecular flows inducing re-braidings. The braiding would also store the highlights of the cellular summer to cellular memory! This could be also seen learning by a modification of various quantum computer programs.

2. Negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is highly suggestive and would conform with the idea that the rule represented by entanglement represents conscious information or information which can become conscious. The process of becoming conscious information could involve ATP$\rightarrow$ ADP and de-activating the flux tube and destroy the information. Time-like braiding represented by liquid flow would modify space-like braiding.

   It is not quite clear whether the information is conscious when negentropic entanglement (and ATP) is present - as Bohm's notion of active information (see `http://tinyurl.com/qhx3suy`) [J18] would suggest - or when ATP is transformed to ADP and connection becomes passive. Negentropic entanglement can be stable with respect to NMP [K58] so that the presence of ATP could mean period of conscious experience - negentropic entanglement could be analogous to active information.

   TGD based model for the memory recall by sending negative energy signals to geometric past suggests that the absorption of negative energy photon transforms ATP to ADP. Conscious experience is regenerated in the geometric now where the negative energy signal came from - perhaps by transforming ADP to ATP by using the negative resulting by sending of negative energy signal! Conscious reading would be actually memory recall and analogous to teleportation? The destruction of the representation of memory in the geometric past would have interpretation in terms of no-cloning theorem (see `http://tinyurl.com/2dhl4oe`) [B2].

3. Static realizations of the programs are easier to imagine since no temporal codes are needed for the transfer of bits. An attractive idea is that the computations are represented by static entanglements for linear structures and that time-like braiding allows to modify the programs.

The realization of program

The program would be basically a sequence of address lists. Address list would contain the address of the function to be performed and the addresses of the input molecules and output molecules. How to represent the address physically?

1. The simplest manner to realize this would use existing flux tubes connecting the processing unit to all possible input and output addresses as well as command addresses, and activate those flux tubes to which input and output data are assigned and reconnect them to the flux tubes connecting processing unit to the unit representing the function. The processing unit would have flux tubes coming from all possible inputs, going to all possible outputs, flux tubes going to places representing functions and coming from these places. Processing unit would be like a relay station or old fashioned telephone center whose sole purpose would be to create connections by reconnecting flux tubes. ATP molecule would be probably involved with the activation and - allowing a sloppy language - one could say that communication line becomes conscious when ATP is attached to it.

   (a) Addressing would be just selection of activated molecules and analogous to that used in telephone network or computer network connected by cables. This would require static flux tube network and flux tubes could be either active or passive. In passive state flux tubes could be short-cut by a reconnection with hydrogen bond so that the ends of cut flux tube would end up to water molecules. This is however not necessary. Activation in absence of the short cut would involve reconnection of a flux tube with a flux tube connecting two parts of ATP - possibly hydrogen bond again- so that ATP becomes part of the flux tubes. If also short cut is involved, the strands coming to the two water molecules reconnect and generate hydrogen bond and flux tube to which

ATP would attach in the proposed manner. As ATP is used it transforms to ADP and de-attaches from the flux tube.

(b) One can imagine also a dynamical addressing based on the generation of magnetic flux tubes between inputs and submodules. The computational process could be still space-like. The first manner to realize dynamical addressing would be by attaching to the ends of dynamical flux tubes biomolecules, which bind to specific receptors. Receptor mechanism would allow to connect distant cells to each other and build a magnetic flux tube connection between them. Computational unit specialized to run a specific program could excrete biomolecules binding to the input and output receptors: this program would realized function in terms of space-like entanglement. Glands (see `http://tinyurl.com/cxjro9z`) excrete hormones binding to receptors and various glands could in principle serve as computational units. Various information molecules bind very selectively and this might also relate to quantum space-like computations.

(c) Second mechanism of dynamical addressing would use dark photons. In this case resonant interaction selecting the target would replace the receptor mechanism. In this kind of situation one can claim that flux tubes are un-necessary, one can use just resonance to build connection to a desired place just as one does in radio communications. Of course, topological light rays could be accompanied by flux tubes. For instance, DNA nucleotide could attach by flux tube to its conjugate in distant DNA molecule and if the connection is based on resonance only similar nucleotide sequences could connect with each other. I have discussed this kind of mechanism in a model for remote replication of DNA (see `http://tinyurl.com/ybvosy7h`) [K116] based on the experimental work by Peter Gariaev and his group. The resonance mechanism could also make possible to establish flux tube connections and the quantum computation could be a static operation.

2. DNA as topological quantum computer vision gives some idea about how the computer program could be realized as a spatial linear structure.

(a) Program would be a sequence of topological quantum computations. Given topological quantum computation would be represented by a braiding of flux tubes connecting DNA nucleotides with the lipid molecules of the inner lipid layer. Program would correspond to a linear sequence of cells with the outer lipid layer connected to the DNA of the second cell.

(b) Lipid flows at given lipid layer could be used to rewrite programs and the programs could respond to the changes in environment in this manner: this would require that the lipid layer is in liquid crystal state during the period when program is changed. Also nerve pulse patterns would induce these flows. Programs would also represent memories as rules realized as quantum abstractions or as quantum functions.

(c) The program would "run" in the spatial direction. The selection of active input and output variables would be by acting the connection from molecule in question by attaching ATP as a relay through which the reconnected flux tube would traverse. This would be also part of the writing of the program. The superposition of entangled inputs and outputs could be seen as a quantum superposition of classical programs assigning outputs to inputs. Also microtubule-lipid layer braiding suggested also to play a key role in the realization of memories could give rise to similar space-like quantum computation representing rules.

(d) The effective 2-dimensionality implied by strong form of holography implied in turn by strong form of general coordinate invariance means that the physics depends on partonic 2-surfaces and 4-D tangent space data at them. This suggests that the dynamics on space-like 3-surfaces and light-like orbits of partonic 2-surfaces is fixed by a process analogous to gauge selection. Does just this effective gauge symmetry make possible to write quantum computer programs? Already ordinary deterministic computer program means selection of one particular dynamics from several alternative options suggesting that strict determinism is broken.

3. What could be the role of bio-catalysis in the computation? Bio-catalysis is a central part of the biological information processing and it would not be surprising if the catalysts connected by flux tubes to substrate molecules were involved with the computations. An attractive idea is that various information molecules binding to receptors involved with bio-control (neurotransmitters, hormones, etc...) are involved with building the flux tube connections between cells. These bio-molecules could carry the ends of flux tubes to special places for which receptors serve as addresses and in this manner build hardware for topological quantum computation involving inputs and outputs in distant parts of the body. The final output could be transformed to controlled gene expression. Quite generally, catalysts bind very selectively and could play a role similar that played by information molecules in building up the quantum computer programs.

4. One can imagine also purely classical computation based on catalytic mechanism probably allowing generalization to quantum case. The idea is that computer program - understood now as dynamical structure - is analogous to what happens in fairy tale in which hero finds a key which fits to a lock of a room containing a key which... There exists a beautiful realization of classical computation in terms of chemical concentrations using DNA. The output of given reaction representing computational step appears in the next reaction provide the system contains additional participating molecules, which could be both substrate molecules and catalysts. The program could be represented as concentrations of molecules needed at intermediate steps and lock-to-key mechanism guarantees that they are performed in the correct temporal order. Inputs and output molecules could be connected by flux tubes to bio-molecules which bind to specific receptors associated with the molecule representing the particular subprogram. This would automatically create a large number of classical computations proceeding in fixed order, maybe even quantum computations.

3.11 Appendix: A Generalization Of The Notion Of Embedding Space

In the following the recent view about structure of embedding space forced by the quantization of Planck constant is described. This view has developed much before the original version of this chapter was written.

The original idea was that the proposed modification of the embedding space could explain naturally phenomena like quantum Hall effect involving fractionization of quantum numbers like spin and charge. This does not however seem to be the case. $G_a \times G_b$ implies just the opposite if these quantum numbers are assigned with the symmetries of the embedding space. For instance, quantization unit for orbital angular momentum becomes n_a where Z_{n_a} is the maximal cyclic subgroup of G_a.

One can however imagine of obtaining fractionization at the level of embedding space for space-time sheets, which are analogous to multi-sheeted Riemann surfaces (say Riemann surfaces associated with $z^{1/n}$ since the rotation by 2π understood as a homotopy of M^4 lifted to the space-time sheet is a non-closed curve. Continuity requirement indeed allows fractionization of the orbital quantum numbers and color in this kind of situation.

3.11.1 Both Covering Spaces And Factor Spaces Are Possible

The observation above stimulates the question whether it might be possible in some sense to replace H or its factors by their multiple coverings.

1. This is certainly not possible for M^4, CP_2, or H since their fundamental groups are trivial. On the other hand, the fixing of quantization axes implies a selection of the sub-space $H_4 = M^2 \times S^2 \subset M^4 \times CP_2$, where S^2 is a geodesic sphere of CP_2. $\hat{M}^4 = M^4 \backslash M^2$ and $\hat{CP}_2 = CP_2 \backslash S^2$ have fundamental group Z since the codimension of the excluded sub-manifold is

equal to two and homotopically the situation is like that for a punctured plane. The exclusion of these sub-manifolds defined by the choice of quantization axes could naturally give rise to the desired situation.

2. Zero energy ontology forces to modify this picture somewhat. In zero energy ontology causal diamonds (CDs) defined as the intersections of future and past directed light-cones are loci for zero energy states containing positive and negative energy parts of state at the two light-cone boundaries. The location of CD in M^4 is arbitrary but p-adic length scale hypothesis suggests that the temporal distances between tips of CD come as powers of 2 using CP_2 size as unit. Thus M^4 is replaces by CD and $\hat{M}^4$ is replaced with $\hat{CD}$ defined in obvious manner.

3. H_4 represents a straight cosmic string inside CD. Quantum field theory phase corresponds to Jones inclusions with Jones index $\mathcal{M} : \mathcal{N} < 4$. Stringy phase would by previous arguments correspond to $\mathcal{M} : \mathcal{N} = 4$. Also these Jones inclusions are labeled by finite subgroups of $SO(3)$ and thus by Z_n identified as a maximal Abelian subgroup.

   One can argue that cosmic strings are not allowed in QFT phase. This would encourage the replacement $\hat{CD} \times \hat{CP_2}$ implying that surfaces in $CD \times S^2$ and $(M^2 \cap CD) \times CP_2$ are not allowed. In particular, cosmic strings and CP_2 type extremals with M^4 projection in M^2 and thus light-like geodesic without zitterwebegung essential for massivation are forbidden. This brings in mind instability of Higgs=0 phase.

4. The covering spaces in question would correspond to the Cartesian products $\hat{CD}_{n_a} \times \hat{CP}_{2n_b}$ of the covering spaces of $\hat{CD}$ and $\hat{CP_2}$ by Z_{n_a} and Z_{n_b} with fundamental group is $Z_{n_a} \times Z_{n_b}$. One can also consider extension by replacing $M^2 \cap CD$ and S^2 with its orbit under G_a (say tetrahedral, octahedral, or icosahedral group). The resulting space will be denoted by $\hat{CD}\hat{\times}G_a$ *resp.* $\hat{CP_2}\hat{\times}G_b$.

5. One expects the discrete subgroups of $SU(2)$ emerge naturally in this framework if one allows the action of these groups on the singular sub-manifolds $M^2 \cap CD$ or S^2. This would replace the singular manifold with a set of its rotated copies in the case that the subgroups have genuinely 3-dimensional action (the subgroups which correspond to exceptional groups in the ADE correspondence). For instance, in the case of $M^2 \cap CD$ the quantization axes for angular momentum would be replaced by the set of quantization axes going through the vertices of tetrahedron, octahedron, or icosahedron. This would bring non-commutative homotopy groups into the picture in a natural manner.

6. Also the orbifolds $\hat{CD}/G_a \times \hat{CP_2}/G_b$ can be allowed as also the spaces $\hat{CD}/G_a \times (\hat{CP_2}\hat{\times}G_b)$ and $(\hat{CD}\hat{\times}G_a) \times \hat{CP_2}/G_b$. Hence the previous framework would generalize considerably by the allowance of both coset spaces and covering spaces.

There are several non-trivial questions related to the details of the gluing procedure and phase transition as motion of partonic 2-surface from one sector of the embedding space to another one.

1. How the gluing of copies of embedding space at $(M^2 \cap CD) \times CP_2$ takes place? It would seem that the covariant metric of M^4 factor proportional to $\hbar^2$ must be discontinuous at the singular manifold since only in this manner the idea about different scaling factor of M^4 metric can make sense. This is consistent with the identical vanishing of Chern-Simons action in $M^2 \times S^2$.

2. One might worry whether the phase transition changing Planck constant means an instantaneous change of the size of partonic 2-surface in CD degrees of freedom. This is not the case. Light-likeness in $(M^2 \cap CD) \times S^2$ makes sense only for surfaces $X^1 \times D^2 \subset (M^2 \cap CD) \times S^2$, where X^1 is light-like geodesic. The requirement that the partonic 2-surface X^2 moving from one sector of H to another one is light-like at $(M^2 \cap CD) \times S^2$ irrespective of the value of Planck constant requires that X^2 has single point of $(M^2 \cap CD)$ as M^2 projection. Hence no sudden change of the size X^2 occurs.

3. A natural question is whether the phase transition changing the value of Planck constant can occur purely classically or whether it is analogous to quantum tunnelling. Classical non-vacuum extremals of Chern-Simons action have two-dimensional CP_2 projection to homologically non-trivial geodesic sphere S^2_I. The deformation of the entire S^2_I to homologically trivial geodesic sphere S^2_{II} is not possible so that only combinations of partonic 2-surfaces with vanishing total homology charge (Kähler magnetic charge) can in principle move from sector to another one, and this process involves fusion of these 2-surfaces such that CP_2 projection becomes single homologically trivial 2-surface. A piece of a non-trivial geodesic sphere S^2_I of CP_2 can be deformed to that of S^2_{II} using 2-dimensional homotopy flattening the piece of S^2 to curve. If this homotopy cannot be chosen to be light-like, the phase transitions changing Planck constant take place only via quantum tunnelling. Obviously the notions of light-like homotopies (cobordisms) and classical light-like homotopies (cobordisms) are very relevant for the understanding of phase transitions changing Planck constant.

3.11.2 Do Factor Spaces And Coverings Correspond To The Two Kinds Of Jones Inclusions?

What could be the interpretation of these two kinds of spaces?

1. Jones inclusions appear in two varieties corresponding to $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$ and one can assign a hierarchy of subgroups of $SU(2)$ with both of them. In particular, their maximal Abelian subgroups Z_n label these inclusions. The interpretation of Z_n as invariance group is natural for $\mathcal{M} : \mathcal{N} < 4$ and it naturally corresponds to the coset spaces. For $\mathcal{M} : \mathcal{N} = 4$ the interpretation of Z_n has remained open. Obviously the interpretation of Z_n as the homology group defining covering would be natural.

2. $\mathcal{M} : \mathcal{N} = 4$ should correspond to the allowance of cosmic strings and other analogous objects. Does the introduction of the covering spaces bring in cosmic strings in some controlled manner? Formally the subgroup of $SU(2)$ defining the inclusion is $SU(2)$ would mean that states are $SU(2)$ singlets which is something non-physical. For covering spaces one would however obtain the degrees of freedom associated with the discrete fiber and the degrees of freedom in question would not disappear completely and would be characterized by the discrete subgroup of $SU(2)$.

   For anyons the non-trivial homotopy of plane brings in non-trivial connection with a flat curvature and the non-trivial dynamics of topological QFTs. Also now one might expect similar non-trivial contribution to appear in the spinor connection of $\hat{CD}\hat{\times}G_a$ and $\hat{CP}_2\hat{\times}G_b$. In conformal field theory models non-trivial monodromy would correspond to the presence of punctures in plane.

3. For factor spaces the unit for quantum numbers like orbital angular momentum is multiplied by n_a *resp.* n_b and for coverings it is divided by this number. These two kind of spaces are in a well defined sense obtained by multiplying and dividing the factors of $\hat{H}$ by G_a *resp.* G_b and multiplication and division are expected to relate to Jones inclusions with $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$, which both are labeled by a subset of discrete subgroups of SU(2).

4. The discrete subgroups of $SU(2)$ with fixed quantization axes possess a well defined multiplication with product defined as the group generated by forming all possible products of group elements as elements of $SU(2)$. This product is commutative and all elements are idempotent and thus analogous to projectors. Trivial group G_1, two-element group G_2 consisting of reflection and identity, the cyclic groups Z_p, p prime, and tetrahedral, octahedral, and icosahedral groups are the generators of this algebra.

By commutativity one can regard this algebra as an 11-dimensional module having natural numbers as coefficients ("rig"). The trivial group G_1, two-element group G_2¡ generated by reflection, and tetrahedral, octahedral, and icosahedral groups define 5 generating elements for this algebra. The products of groups other than trivial group define 10 units for this algebra so that there are 11 units altogether. The groups Z_p generate a structure analogous to natural numbers acting as analog of coefficients of this structure. Clearly, one has effectively 11-dimensional commutative algebra in 1-1 correspondence with the 11-dimensional "half-lattice" N^{11} (N denotes natural numbers). Leaving away reflections, one obtains N^7. The projector representation suggests a connection with Jones inclusions. An interesting question concerns the possible Jones inclusions assignable to the subgroups containing infinitely manner elements. Reader has of course already asked whether dimensions 11, 7 and their difference 4 might relate somehow to the mathematical structures of M-theory with 7 compactified dimensions. One could introduce generalized WCW spinor fields in the WCW labelled by sectors of H with given quantization axes. By introducing Fourier transform in N^{11} one would formally obtain an infinite-component field in 11-D space.

The question how do the Planck constants associated with factors and coverings relate is far from trivial and I have considered several options.

1. If one assumes that $\hbar^2(X)$, $X = M^4$, CP_2 corresponds to the scaling of the covariant metric tensor g_{ij} and performs an over-all scaling of metric allowed by Weyl invariance of Kähler action by dividing metric with $\hbar^2(CP_2)$, one obtains $r^2 \equiv \hbar^2/\hbar_0^2\hbar^2(M^4)/\hbar^2(CP_2)$. This puts M^4 and CP_2 in a very symmetric role and allows much more flexibility in the identification of symmetries associated with large Planck constant phases.

2. Algebraist would argue that Planck constant must define a homomorphism respecting multiplication and division (when possible) by G_i. This requires $r(X) = \hbar(X)\hbar_0 = n$ for covering and $r(X) = 1/n$ for factor space or vice versa. This gives two options.

3. Option I: $r(X) = n$ for covering and $r(X) = 1/n$ for factor space gives $r \equiv \hbar/\hbar_0 = r(M^4)/r(CP_2)$. This gives $r = n_a/n_b$ for $\hat{H}/G_a \times G_b$ option and $r = n_b/n_a$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for hybrid cases.

4. Option II: $r(X) = 1/n$ for covering and $r(X) = n$ for factor space gives $r = r(CP_2)/r(M^4)$. This gives $r = n_b/n_a$ for $\hat{H}/G_a \times G_b$ option and $r = n_a/n_b$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for the hybrid cases.

5. At quantum level the fractionization would come from the modification of fermionic anti-commutation (bosonic commutation) relations involving $\hbar$ at the right hand side so that particle number becomes a multiple of $1/n$ or n. If one postulates that the total number states is invariant in the transition, the increase in the number of sheets is compensated by the increase of the fundamental phase space volume proportional to $\hbar$. This would give $r(X) \to r(X)/n$ for factor space and $r(X) \to nr(X)$ for the covering space to compensate the n-fold reduction/increase of states. This would favor Option II.

6. The second manner to distinguish between these two options is to apply the theory to concrete physical situations. Since G_a and G_b act as symmetries in CD and CP_2 degrees of freedom, one might of being able to distinguish between the two options if it is possible to distinguish between the action of G as symmetry of quantum states associated with covering and factor space. Also the quantization of the orbital spin quantum number at single particle level as multiples of n can be distinguished from that in multiples of $1/n$.

3.11.3 A Simple Model Of Fractional Quantum Hall Effect

The generalization of the embedding space suggests that it could possible to understand fractional quantum Hall effect [D1] at the level of basic quantum TGD. This section represents the first rough model of QHE constructed for a couple of years ago is discussed. Needless to emphasize, the model represents only the basic idea and involves ad hoc assumption about charge fractionization.

Recall that the formula for the quantized Hall conductance is given by

$$\begin{aligned} \sigma &= \nu \times \frac{e^2}{h} \ , \\ \nu &= \frac{n}{m} \ . \end{aligned} \tag{3.11.1}$$

Series of fractions in $\nu = 1/3, 2/5, 3/7, 4/9, 5/11, 6/13, 7/15..., 2/3, 3/5, 4/7, 5/9, 6/11, 7/13..., 5/3, 8/5, 11/7, 14/9...4/3, 7/5$ $1/5, 2/9, 3/13..., 2/7, 3/11..., 1/7....$ with odd denominator have been observed as are also $\nu = 1/2$ and $\nu = 5/2$ states with even denominator [D1].

The model of Laughlin [D14] cannot explain all aspects of FQHE. The best existing model proposed originally by Jain is based on composite fermions resulting as bound states of electron and even number of magnetic flux quanta [D10]. Electrons remain integer charged but due to the effective magnetic field electrons appear to have fractional charges. Composite fermion picture predicts all the observed fractions and also their relative intensities and the order in which they appear as the quality of sample improves.

The generalization of the notion of embedding space suggests the possibility to interpret these states in terms of fractionized charge, spin, and electron number. There are four combinations of covering and factors spaces of CP_2 and three of them can lead to the increase of Planck constant. Besides this there are two options for the formula of Planck constant so that which the very meager theoretical background one can make only guesses. On the following just for fun consideration option I is considered although the conservation of number of states in the phase transition changing $\hbar$ favors option II.

1. The easiest manner to understand the observed fractions is by assuming that both M^4 and CP_2 correspond to covering spaces so that both spin and electric charge and fermion number are fractionized. This means that e in electronic charge density is replaced with fractional charge. Quantized magnetic flux is proportional to e and the question is whether also here fractional charge appears. Assume that this does not occur.

2. With this assumption the expression for the Planck constant becomes for Option II as $r = \hbar/\hbar_0 = n_a/n_b$ and charge and spin units are equal to $1/n_b$ and $1/n_a$ respectively. This gives $\nu = nn_a/n_b$. The values $m = 2, 3, 5, 7, ..$ are observed. Planck constant can have arbitrarily large values. There are general arguments stating that also spin is fractionized in FQHE.

3. The appearance of $\nu = 5/2$ has been observed [D8]. The fractionized charge is $e/4$ in this case. Since $n_i > 3$ holds true if coverings are correlates for Jones inclusions, this requires to $n_b = 4$ and $n_a = 10$. n_b predicting a correct fractionization of charge. The alternative option would be $n_b = 2$ that also Z_2 would appear as the fundamental group of the covering space. Filling fraction $1/2$ corresponds in the composite fermion model and also experimentally to the limit of zero magnetic field [D10]. $n_b = 2$ is however inconsistent with the observed fractionization of electric charge and with the vision inspired by Jones inclusions.

4. A possible problematic aspect of the TGD based model is the experimental absence of even values of n_b except $n_b = 2$ (Laughlin's model predicts only odd values of n). A possible explanation is that by some symmetry condition possibly related to fermionic statistics (as in Laughlin model) n_a/n_b must reduce to a rational with an odd denominator for $n_b > 2$. In other words, one has $n_a \propto 2^r$, where 2^r the largest power of 2 divisor of n_b.

5. Large values of n_a emerge as B increases. This can be understood from flux quantization. One has $e\int BdS = n\hbar(M^4) = nn_a\hbar_0$. By using actual fractional charge $e_F = e/n_b$ in the flux factor would give $e_F\int BdS = n(n_a/n_b)\hbar_0 = n\hbar$. The interpretation is that each of the n_a sheets contributes one unit to the flux for e. Note that the value of magnetic field in given sheet is not affected so that the build-up of multiple covering seems to keep magnetic field strength below critical value.

6. The understanding of the thermal stability is not trivial. The original FQHE was observed in 80 mK temperature corresponding roughly to a thermal energy of $T \sim 10^{-5}$ eV. For graphene the effect is observed at room temperature. Cyclotron energy for electron is (from $f_e = 6\times10^5$ Hz at $B = .2$ Gauss) of order thermal energy at room temperature in a magnetic field varying in the range 1-10 Tesla. This raises the question why the original FQHE requires so low temperature. The magnetic energy of a flux tube of length L is by flux quantization roughly $e^2B^2S \sim E_c(e)m_eL$ ($\hbar_0 = c = 1$) and exceeds cyclotron roughly by a factor L/L_e, L_e electron Compton length so that thermal stability of magnetic flux quanta is not the explanation. A possible explanation is that since FQHE involves several values of Planck constant, it is quantum critical phenomenon and is characterized by a critical temperature. The differences of the energies associated with the phase with ordinary Planck constant and phases with different Planck constant would characterize the transition temperature.

As already noticed, it is possible to imagine several other options and the identification of charge unit is rather ad hoc. Therefore this model can be taken only as a warm-up exercise.

Chapter 4

The Notion of Wave-Genome and DNA as Topological Quantum Computer

4.1 Introduction

For about eight years ago - inspired by a representation in CASYS′2000 conference [I63] - I developed a model [K112, K19] for the fascinating effects of laser light on genome discovered by Peter Gariaev and his collaborators. This model is somewhat obsolete since it does not involve the recent TGD inspired vision about quantum biology and DNA, and the discussions with Peter in the second Unified Theories conference 2008 in Budapest made clear the need to update this model containing also some misinterpretations.

In this article the effects of laser light on living matter are discussed only briefly with a stronger emphasis on the photographs produced by the scattering of ordinary light on DNA reported in [I74]. In TGD framework these photographs could be interpreted as photographs of wormhole magnetic flux tubes containing dark matter. This would realize the dream of making directly visible the basic new structure predicted by TGD inspired quantum biology. Of course, a more conventional explanation might be found for the effect, but the proposed qualitative explanation deserves to be discussed since it fits nicely with the general vision about dark matter in TGD Universe.

4.1.1 The Findings Of Peter Gariaev And Collaborators

These findings of Gariaev and collaborators include the rotation of polarization plane of laser light by DNA [I63]. phantom DNA effect [I64]. the transformation of laser light to radio wave photons having biological effects [I65]. the coding of DNA sequences to the modulated polarization plane of laser light and the ability of this kind of light to induce gene expression in another organisms provided the modulated polarization pattern corresponds to an "address" characterizing the organism [I63]. and the formation of images of what is believed to be DNA sample itself and of the objects of environment by DNA sample in a cell irradiated by ordinary light in UV-IR range [I74].

Gariaev and collaborators have introduced the notion of wave genome [I63] requiring the coding of DNA sequences to temporal patterns of coherent em fields forming a bio-hologram representing geometric information about the organism. Code could mean that nucleotide is represented by a characteristic rotation angle for the polarization plane of linearly polarized laser radiation scattering from it. This kind rotation is known to be induced by chromosomes by a mechanism which to my best knowledge is poorly understood. Other open questions concern the precise identification of the substrate of the bio-hologram, of the reference wave and of information carrying wave, and of the mechanism making possible (quantum) coherence in macroscopic length scales.

The reading of the DNA sequence to a radiation pattern is assumed to rely on the propagation of an acoustic soliton along DNA [I63]. Whatever this process is, one should also identify the reverse process inducing the activation of the genome as the target organism receives the radiation coding for the DNA provided the "address" is correct. One should also identify the mechanism transforming laser radiation to radio-waves at various frequencies as well as the mechanism creating what is believed to be the image of DNA sample and replicated images of some instruments used in experiment.

4.1.2 The Relevant Aspects Of TGD Based View About Living Matter

The called massless extremals (MEs or topological light rays) distinguish between TGD and Maxwell's electrodynamics: they represent classically signals propagating with light velocity in a precisely targeted and dispersion free way, and are therefore excellent candidates for the communication and control tools in the TGD based model for a living system as a conscious hologram [K67, K19, K33]. The notion of magnetic/field body, which can have layers of even astrophysical size, is an essential element of the model. Magnetic body uses biological body as a sensory receptor and motor instrument and MEs mediate sensory input and control signals between the two kinds of bodies [K33]. I have already earlier applied MEs and the notion of magnetic body in an attempt to understand Gariaev's findings [K19].

The new element is the model for DNA as topological quantum computer (TQC) [K3] based on time-like braidings of so called wormhole magnetic flux tubes connecting nucleotides to the lipids at lipid layers nuclear and cell membranes. The model leads to a wide variety of predictions about DNA itself [K3]. to a universal model for a tissue memory in terms of space-like braidings of wormhole magnetic flux tubes [K3]. to a more detailed model of nerve pulse explaining also the origin of EEG and its synchrony [K79]. to a model for the evolution of the genetic code [**?**]. to a model of catalyst action involving a phase transition reducing the value of Planck constant inducing the shortening of the flux tubes connecting the reacting molecules and thus forcing them to the vicinity of each other, and to a model of for protein folding [K7] in which the presence of wormhole magnetic flux tubes connecting bio-molecules becomes almost a definition for what it is to be living. It is interesting to combine these new ideas with the earlier [I63, I65] and more recent [I74] findings of Gariaev. Basically the challenge is to fuse the DNA as TQC model with the model of living systems as a conscious hologram [K19].

4.1.3 The Basic Assumptions Of Model Explaining Findings Of Gariaev

The basic assumptions of the model to be discussed are following.

1. The hierarchy of Planck constants requires a generalization of the notion of 8-D embedding space $H = M^4 \times CP_2$ obtained by gluing together almost copies of H like pages of book along common back. The pages of the book carry matter with various values of Planck constant and the particles at different pages of the book are dark relative to each other in the sense that they cannot appear in the same vertex of Feynman diagram. The particles at different pages of the book can however interact via classical fields and via the exchange of (for instance) photons which suffer a phase transition changing Planck constant as they leak between pages of the book. In principle it is therefore possible to photograph the magnetic flux tubes carrying dark matter, and the proposal is that this is what Gariaev and collaborators have actually achieved [I74].

2. Braid strands realized as wormhole magnetic tubes are identified as correlates for a directed attention. DNA connected by strands to (say) experimental instrument directs its attention to the instrument. One could perhaps say that DNA "sees" the surrounding world. Also ordinary attention for vision and other senses could involve flux tubes connecting DNA to the object of perception. This explains the ability of DNA to generate images of objects of external world [I74] . The hierarchy of Planck constants explains the transformation of laser light to radio waves [I65] as a phase transition increasing Planck constant and thus also wavelength but keeping the energy of photons as such.

3. Wormhole flux tubes carrying super-conducting matter in large $\hbar$ phase are characterized by anomalous em charges characterizing the nucleotides [K3]. and thus define an excellent candidate for the substrate of bio-hologram. A coding of DNA nucleotides to the rotation

of polarization plane results for photons traversing through these flux tubes if a large parity breaking making possible rotation of the polarization plane (Faraday effect) is assumed. This is possible by the large parity breaking of fractally scaled up variant of weak physics [K12] explaining also chiral selection.

4. The model for the nerve pulse [K79] leads to the model of EEG waves in which EEG rhythms induce a complete analog of reference waves whereas nerve pulse induces the analog of information carrying wave [K33]. The model predicts a fractal hierarchy of EEGs (EXGs) and their counterparts associated with long ranged color and electro-weak gauge fields having MEs as classical correlates. EEG rhythms are associated with propagating soliton sequences and nerve pulse corresponds to a propagating perturbation associated with this soliton sequence rather than soliton. The model predicts automatically the synchrony and spatiotemporal coherence of neural firing. EEG photons correspond to a large value of Planck constant implying that their energies are above thermal energy at physiological temperatures so that their effects on living matter are not masked by thermal noise.

   This model generalizes essentially as such to the recent context: the counterparts of nerve pulses propagate along the complex formed by DNA connected to the nuclear or cell membrane or even to another cell nucleus by flux tubes. The prediction is that gene expression can be coherent in the scale of organ and even that of population. This conforms with the notion of super-genome stating that the sequences of DNA strands in different nuclei organize along magnetic flux sheet like text lines at the page of a book. The notion of hyper-genome means that these books from different organisms in turn organize to a pages of a book at higher level of fractal hierarchy and give rise to a gene expression at the level of population or even biosphere.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L6].

4.2 TGD Counterpart For Wave Genetics

The wave genetic model of Gariaev involves the assumption that soliton waves propagating along DNA induce the reading of DNA sequence to a pattern of radiation. DNA is known to rotate the polarization plane but it is unclear how the coding of DNA sequence to a rotation of polarization plane could be achieved.

Second key element is the notion of bio-hologram. It is assumed that fractality is somehow involved. The key questions are following.

1. What is the substrate of the bio-hologram assuming that it is not based on nonlinear action for electromagnetic field (four-wave mechanism)? The substrate should have size larger than wavelength so that chromosomes are too thin to act as substrate.

2. What guarantees coherence or even quantum coherence in macroscopic scales?

3. How reference wave and the wave carrying the information are represented?

4.2.1 The Notion Of Bio-Hologram In TGD Framework

TGD based model is based on the model of living matter inspired by the model of DNA as topological quantum computer [K3]. DNA is connected to other bio-molecules and also to lipid layers of nuclear and cell membrane by wormhole magnetic flux tubes providing a representation of the genetic code. Braids strands defined by the flux tubes make possible topological quantum computation with TQC programs coded by dynamical braidings of the flux tubes induced by the water flow near the vicinity of cell and nuclear membranes inducing the flow of the 2-D liquid crystal defined by the lipids of the membrane. Flux tubes are dynamical, being able to reconnect and in the case of wormhole flux tubes even disappear without breaking conservation of magnetic flux, and they serve as correlates for a directed attention at the molecular and perhaps even at higher levels. Dark matter at the flux tubes has a large value of Planck constant and therefore a slow dissipation rate. Also superconductivity is possible and the predicted exotic nuclear physics allows bosonic chemical equivalents of all biologically important ions. Long range color and electro-weak interactions implying in particular large parity breaking are possible and could explain chirality selection in living matter.

It is easiest to introduce the model through questions and answers.

Q: What is the substrate of the bio-hologram and how coherence is obtained?

A: Magnetic flux tubes with large $\hbar$ define the substrate and make possible macroscopic quantum coherence. Visible photons can suffer a phase transition to large $\hbar$ variants with wavelengths scaled up like $\hbar$. The interpretation would be in terms of bio-photons and their dark variants [I70].

Q: How the Faraday effect results?

A: Flux tubes contain charged particles in super-conducting state so that diamagnetism results. Large parity breaking makes possible different propagation velocities for the two circular polarizations and thus Faraday effect resulting via the splitting of the linearly polarized wave to two circular polarizations fusing back again at the second end of the flux tube. The magnetic field along flux tubes induces Faraday rotation and codes DNA nucleotide to the rotation angle of the polarization plane.

Q: How coding is achieved?

A: Coding is achieved by the different total charges associated with flux tubes implying that the rotation angles for polarization plane depend on nucleotide. This would be made possible by anomalous em charge associated with DNA sheet of wormhole flux tube implying that the rotation of polarization plane is different for each nucleotide [K3].

Q: What is the identification of reference wave and for the wave representing the information?

A: The model for nerve pulse and EEG suggests that reference waves are induced as Josephson radiation from voltage waves propagating along DNA and represent a fractal variant of EEG. The voltages waves generating reference waves correspond to propagating soliton sequences for Sine-Gordon equation describing idealized cylindrical Josephson junction having as an analog series of coupled gravitational penduli. The propagating soliton sequence along DNA with constant phase differences between subsequent penduli would generate the reference wave as Josephson radiation. The analog of nerve pulse would result as one pendulum kicked so that it begins to oscillate instead of rotating and induces an propagating localized oscillation.

Microscopically cylindrical Josephson junction decomposes into junctions defined by the flux tubes and Josephson currents between the ends of the flux tubes generate em radiation as coherent photons. Josephson radiation would therefore give rise to bio-photons and their dark variants with same photon energy but scaled up wavelength. Obviously the transformation of laser photons to radio-wave photons can be understood in terms of this mechanism and the quantization of Planck constant implies quantization of the energies involved.

4.2.2 How To Fuse The Notion Of Bio-Hologram With The Model Of DNAs TQC?

In the most economical picture - inspired by what is known about ordinary computers - intronic sequences would represent the names for TQC programs constructed from basic modules and expressing their outcomes chemically. Calling of the name of TQC would activate the TQC. This would allow an extremely rich combinations of basic modules, explain why the intronic portion of DNA increases during evolution, and why organisms with essentially identical genomes can be at widely differing evolutionary levels (say humans and apes). A further nice feature is that the intronic DNA of a given organism can induce gene expression in an organism for which the genes involved are not identical so that mutations would not be fatal. The prediction is that addresses represented by introns and the portions of promoter regions representing the conjugates of these addresses should be highly conserved.

The reading of the name of TQC to a polarization modulation pattern of incoming light would generate a signal which initiates TQC program in another cell in the case that the reverse polarization to the same linear polarization along the entire length of receiving intronic piece - conjugate of the original - takes place. The resulting overall linear polarization should initiate TQC leading to the eventual gene expression. Why the condition that linear polarization is same along entire piece of the "name" is not quite clear.

Introns could be connected by flux tubes to a part of DNA initiating gene expression. One would expect that this portion of gene is conjugate of the intronic portion containing the name of submodule. This would make possible RAM type representation of TQC programs if the link to next activated part of genome is represented by this same mechanism: exactly similar mechanism realizes links electromagnetically in web. A nucleus performing TQC infects large number of nuclei to perform the same TQC. Same could occur even at the level of population since very large values of $\hbar$ are possible.

4.3 The Effects Of Laser Light On Living Matter

The effects of laser light on living matter are discussed in the following briefly from TGD point of view.

4.3.1 Phantom DNA Effect

In phantom DNA effect [I64] there is an elastic scattering of the coherent laser radiation from irradiated DNA. When one removes the DNA from the chamber containing it, and irradiates it by laser light, a weak pattern of scattered light is still produced as if there were a kind of phantom DNA there. The pattern can last for months.

For years ago I considered an explanation of the effect based on dropping of part of DNA to larger space-time sheets characterized by larger value of p-adic prime and remaining in the vessel as visible DNA is removed [K112, K19]. A variant of this explanation inspired by the dark matter hierarchy is that the anomalous scattering takes place on dark DNA at wormhole flux tubes remaining in the vessel.

The most science fictive possibility is that the flux tubes connect the vessel boundaries to the removed DNA by wormhole flux tubes which are very long and correspond to a large value of $\hbar$. In this case the scattering would involve a phase transition increasing the value of Planck constant and a travel of photons to the removed DNA and back followed by a phase transition to ordinary photons.

Similar explanation works also in the case of homeopathy and allows to understand why the classic experiments of Benveniste [I59, I60] could not be replicated when experimenters did not know which bottles contained the treated water [K48]. In this case the molecules dissolved in water would lose their magnetic bodies as a consequence of the shaking of the homeopathic remedy and one can say that clusters of water molecules would steal their magnetic coats. This would allow them to mimic the behavior of molecules and their presence would allow the immune system would develop a resistance against real molecules. This of course works only if the cyclotron radiation from the magnetic body is responsible for the biological effects. It is known that em radiation at low frequencies is indeed responsible for the ability of molecules to recognize each other. The generation of cyclotron radiation requires metabolic energy and the magnetic flux tubes connecting the experimenter to the treated bottle of water (correlates for directed attention) could have served as bridges along which metabolic energy could be transferred by using topological light rays (MEs serving as TGD counterparts of Alfven waves). Experimentalists certainly did have strong desire to have successful experiments and this helped to realize the transfer of the metabolic energy.

4.3.2 Effects Of The Polarization Modulated Laser Light On Living Matter

Polarized light with a suitable temporal pattern for the modulation of polarization direction induces biological effects. The effects are not caused to arbitrary target and one can say that the part of target genome involved has an address characterized by a temporal pattern of polarization modulation resulting in the propagation of the scaled variant of nerve pulse along chromosome. DNA is known to induce a rotation of polarization plane of incoming linearly polarized light and Gariaev suggests that the address is due to the propagation of a soliton along DNA inducing the modulation [I63].

TGD based model for the rotation of the polarization plane is based on Faraday effect [K11].

1. Usually diamagnetic dielectric causes the Faraday effect. The effect is due to different propagation velocities of left and right circular polarizations and recombination of polarizations to linear polarization. The rotation of the polarization plane would be caused by a Faraday effect at flux tubes. Superconductivity would imply ideal diamagnetism. Dielectric property is probably not present but large parity breaking due to long range weak interactions [K12] could explain why circular polarizations propagate with different velocities. Strong parity breaking could be caused by the presence of electro-weak gauge fields behaving like massless fields below the cell length scale and would explain also chiral selection. For large values of $\hbar$ the range of these fields would be scaled up accordingly.

2. The travel of the photon along a transversal flux tube starting from DNA nucleotide induces a rotation of the direction of polarization plane. The reverse rotation of polarization plane takes place as the light propagates in the reverse direction. The reverse propagation restoring the original overall linear polarization is expected to induce the biological along the portion of DNA in question. Phase conjugate light might be also involved.

3. The coding of DNA sequences to radiation patterns results since the charge Q associated with the nucleotide end of the wormhole magnetic flux tube affects Faraday rotation and is different for each nucleotide. The value of the charge is given by $Q = -2+Q_a$, where -2 units come from phosphate and Q_a corresponds to the charge of the quark (u, d) or antiquark $\overline{u}$, $\overline{d}$) at the DNA space-time sheet associated with wormhole magnetic flux tube formed by a pair of space-time sheets connected by wormhole contacts having at its light-like throats quark and antiquark [K3]. Hence the rotation of the polarization plane depends on the nucleotide.

4.3.3 Plr Spectroscopy

Bio-systems could generate holograms in much more concrete sense than the wetty and hot and noisy character of this environment would suggest: even mechanisms generating laser beams could be there. The findings of Peter Gariaev and collaborators described in the article "The spectroscopy of bio-photons in non-local genetic regulation" [I65] led to a concrete model for how bio-photons affect many-sheeted DNA, and in this manner induce a generation of coherent radio waves and ELF waves [K19]. The recent picture brings in the hierarchy of Planck constants and suggests a modification of this model.

The effect

In polarizing laser-radio wave spectroscopy (PLR-spectroscopy) laser light scatters from the target substance. In the experiments of Gariaev *et al* red light ($\lambda = 632.8$ nm, 1.9595 eV) generated by He-Ne laser is used. This energy actually corresponds very precisely to one of the fundamental metabolic energy quanta identified as liberated zero point kinetic energy of proton as it drops from certain space-time sheet to much larger space-time sheet. There are two orthogonal polarizations correlated in intensity in such a way that the total intensity remains constant. After the interaction of one mode with the target substance, the reflected light is returned to the optical resonator, where the re-distribution of the intensity of these modes occurs. One of the laser modes, at a certain mode of generation, is able during the interaction with the target substance to induce polarization modulated radio waves of a wide spectrum correlated with the modulations of the optical modes of the laser radiation. The modulation is assumed to relate to rotational fluctuations of micro-structural components (say, domains of crystals) and of their optical activity. The PLR-spectrum is present also for in-organic materials. For biological targets there is spectral memory effect present, which means that the radio wave radiation continues even when the laser beam is not present anymore.

The frequency interval of the radio emission settles down at the 1 MHz. The PLR-spectrum is depicted in figures 1 and 2 of [I65] for apofillit crystal. The frequency spectrum for the radio waves has a modulated fractal structure suggesting that spectrum is superposition of spectra which consist of harmonics $n_1 f_h - n_2 f_l$ of higher frequency f_h modulated by harmonics of scaled down frequency $f_l = x f_h$. Almost identical copies of a piece of length about

$$\Delta f \sim 100\ Hz$$

appear in a sequence as the pictures 1 and 2 of [I65] for the spectrum of apofillit crystal in 1560-1860 Hz range demonstrate. This suggests the presence of harmonics of basic frequencies perhaps shifted by a constant amount. Cyclotron and spin flip transitions in magnetic field suggest itself.

There is also gross structure consisting of peaks in scale of kHz suggesting harmonics of frequency of order kHz. For wheat seed (picture 3 of [I65]) the strongly expressed frequency ranges are identified as 800-900 Hz (to my personal opinion the band is 300-900 Hz), 1700-1900 Hz, 2400-2600 Hz, 3600-3800 Hz (to my personal opinion a wider frequency range 1700-2200 Hz is strongly expressed). There is also strongly expressed frequency band below 300 Hz. Also the spectrum of high polymerization DNA sample from calf thymus (picture 4 of [I65]) shows a clear peak at 2400-2600 Hz and less pronounced peaks at lower frequencies.

The radio wave radiation from DNA samples is accompanied by specific effects on bio-systems such as ab-normally fast germination and re-vitalization of seeds. Thus it seems that the radio wave radiation is able to restore the genetic control apparatus and the vitality of the seeds.

TGD based explanation of the effect

Dark matter hierarchy suggests the interpretation of radio-wave photons as large $\hbar$ photons with energy equal to that of the original photon. Biophotons and their dark variants could form Bose-Einstein condensates at the wormhole magnetic flux tubes. The flux tubes associated with DNA would transform laser photons to radio wave photons by inducing $\hbar$ increasing phase transition. Large value of $\hbar$ would increase the range of interactions so that they would become possible even in the scale of biosphere. In particular, coherent gene expression in the scale of organism and even population. Genetic code could be represented as radiation patterns with the charges assignable to the end of DNA space-time sheet of flux tube providing the coding.

4.4 The Scattering Of Incoherent UV-IR Light On DNA

The proposed model for the findings about scattering of incoherent UV-IR light from DNA lead to an amazing conclusion that the experiments make directly visible the magnetic flux tubes containing dark matter.

4.4.1 Basic Facts

The figures of the article [I74] give valuable information about what is involved. There are two experimental arrangements.

1. In the first experiment dry/dehydrated DNA is contained in a small seal containing a conical cylinder (4 cm long, .9 cm at its upper end) or 3 ml of DNA water solution 1 mg/ml. The radiation by UV-C lamp lasts for 10 minutes: note that UV-C wavelengths are in the range 280-10 nm.

2. In the second experiment the DNA sample is in open cell and a light source known as Duna-M irradiates red light from 21 LEDS (650 nm) and IR light (920 nm) from 16 LEDs. Also UV-B lamp and Compact electronic CEST26E17 Black lamp are involvedUV-B wavelengths are in the range 315-280 nm. The light sources are turned on and off with intervals of 2-3 seconds. The exposure time is 1 second.

   The basic findings are following [I74].

1. The effects occur only if the sample contains DNA.

2. A large number (tens) of closely spaced replica images of nearby objects, in particular the red LED. The replicas for the image of instrument are along strictly horizontal half line (see **Fig.** 1).

3. The replica sequences of the instruments appear periodically suggesting that the energy of incoming photons is gradually accumulated and liberated in a burst. The interference by an external DNA source (touching by finger of DNA cell) changes the direction of the half line which disappears at the next exposure to white light.

4. Single vertical curved band like image of roughly the same height as the entire image and with more or less the same width as the distance between replicas of the instrument parts appears to the left from the instrument image (see **Fig. 4.1**). This image is not replicated in the horizontal direction. The fine structure of the band for one of the reported images (see **Fig. 4.2**) however suggests that also the band like structure consists of replicas of same size as the replicas associated with instruments. The band like structure for second method decomposes to 5 red parallel curves (see **Fig. 4.3**) for which the interpretation as images of 5 red LEDs is proposed based on the observation that these LEDs irradiate directly the DNA cell. The phantom of DNA image remains intact for some time after the irradiation.

If I have understood correctly, the interpretation proposed in [I74] is following.

1. The sequence of the horizontal images of the instrument would result from a motion of single image moving during the exposures: this requires that the motion is fast in the time scale of exposure. The appearance of equally spaced replicas forces to assume that the motion occurs in discrete jumps in horizontal direction.

2. The band like structure is identified as the image of DNA sample. The band is assumed to correspond to a discrete and non-predictable motion of single image.

There are objections against the idea that the motion of single image produces the image. In particular, the discreteness of the motion looks strange. One can also wonder why the motion for the image of the instrument is strictly horizontal whereas the motion of DNA image is not horizontal and is curvilinear. One can also ask whether the an image of DNA sample is actually in question since the position of the band like structure is to left from the cell containing the DNA.

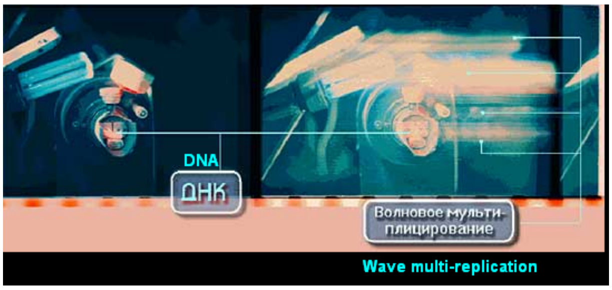

Figure 4.1: The left hand side figure is from [I74] and represents the replica images of the instruments and the image interpreted by experimenters as a replica image of DNA sample (second method).

4.4.2 TGD Based Model For The Replicas

One can consider two models for the replicas. The first model assumes that the images are images of dark magnetic flux tubes. Second model assumes that in the case of instrument images diffraction is involved.

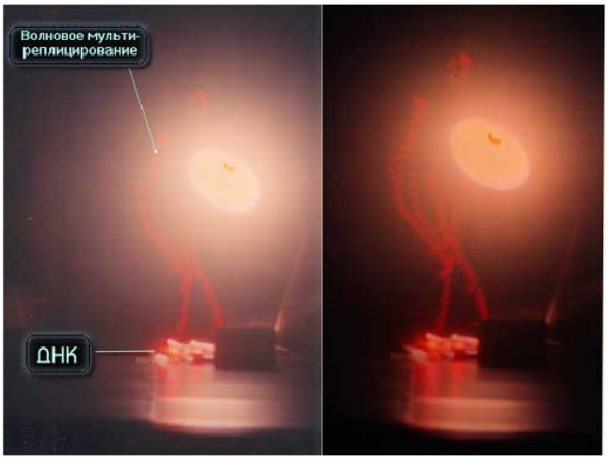

Figure 4.2: The picture shows the discrete replica like structure of the band like image interpreted by experimenters as replica image of DNA sample (first method).

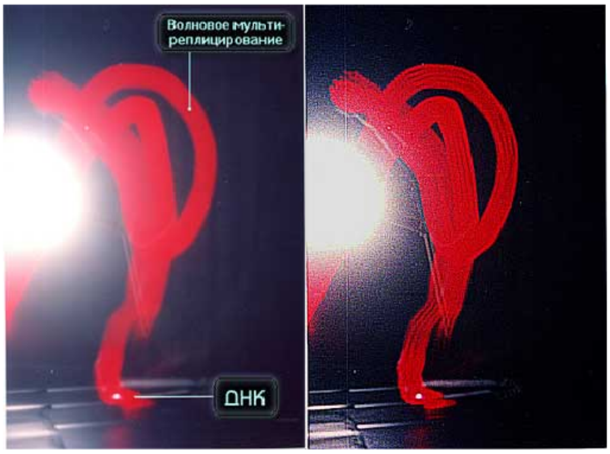

Figure 4.3: The picture reveals the 5-fold fine structure of the band like image interpreted by experimenters as replica image of DNA sample. The 5-fold character probably correspond to five red LEDs above the sample (second method).

Have wormhole magnetic magnetic flux tubes containing dark matter been photographed?

The most elegant model for the effects found hitherto relies on the assumption that both the horizontal replica sequences and the band like structures having also replica structure correspond to real structures, most naturally (wormhole) magnetic flux tubes. In the case of instrument replicas they would emanate directly from the instruments. In the case of DNA image they would emanate from a position to the left from the cell containing DNA. The presence of DNA should somehow generate the flux tubes.

1. In the case of horizontal replications of instruments the replicas would be associated with a magnetic flux tube emanating horizontally from the instruments to the right. Replicas would be obtained if a dipole distribution assignable to the surface of object and representable in terms of Fourier transform restricted to a box containing the object and having discrete momentum spectrum is extended to a periodic Fourier transform along the horizontal flux

tube. Flux tube would thus represent a series of images of the geometric object and this would make possible to communicate the data through long distances.

2. Also the DNA image could be the image of a curved flux tube assignable to the cell containing the DNA. The band like structure does not however begin from the cell containing DNA being located left from it. A possible explanation is that there topological light ray connecting the cell containing DNA to a similar sized cell at the end of the flux tube irradiating it with photons emitted from the dipole distribution at its surface. The resulting induced dipole distribution representable in terms of a discrete Fourier transform is then continued along the entire curved flux tube and would generate the replicas.

3. The replication of the dipole distribution along the entire length of the flux tube requires macroscopic quantum coherence suggesting a large value of Planck constant. If the coherence is required at least in the length scale L of the flux tube, one obtains ratio $r = \hbar/\hbar_0 \geq L/\lambda \simeq 10^6$ for $L = .5$m and $\lambda = 500$ nm. This value could correspond to the favored value $r = 2^{20}$ and thus to a favored value of Planck constant [K36]. A weaker condition is obtained by replacing L with the size a of the cell giving $r \geq a/\lambda \simeq 2 \times 10^5$ for $a = .1$ m.

4. If the flux tubes correspond to large value of Planck constant, the dark photons emanating from them must transform to ordinary photons since diffractive effects are not involved.

5. The fact that the images of the flux tubes appear periodically suggests that a Bose-Einstein condensate of dark photons is gradually formed at them which bursts out as some critical number of dark photons are present and leaks to the visible sector of the 8-D embedding space becoming ordinary photons. One can visualize the sectors of the generalized 8-D embedding space as pages of a book characterized by different values of Planck constant so that the leakage would occur from page to another one through the back of the book.

6. The effect of touching in the second type experiment involving LEDs can be understood if the touching reverses the direction of the magnetic flux tubes assigned with the instruments. The disappearance of the replicated instrument image 5-8 seconds after the touching could relate to the instability of the right-oriented flux tubes. If the right-directed flux tube is mirror image of the left oriented flux tube, the instability might relate to a parity breaking possible in TGD Universe by the presence of scaled variants of weak interactions. The preferred orientation of the flux tube might be also determined by something in environment, say resources of metabolic energy. If the flux tubes are correlates for attention, one can even imagine that DNA with the mediation of flux tubes directs its attention to something interesting.

There are also some open questions.

1. Why the flux tube assignable to the DNA is curved and why the image of this flux tube does not emanate from the sample?

2. How the presence of DNA induces the generation of the flux tubes? The model for DNA as TQC would suggest that the thin wormhole magnetic flux tubes connecting DNA to the instruments induce the effect, and that the flux tubes explaining the image correspond to higher level structures with larger value of Planck constant and are somehow induced by the presence of DNA. They could also correspond to a larger value of p-adic prime but same value of Planck constant. Perhaps one might say that the magnetic body of DNA makes the instruments in some sense part of its biological body by directing its attention to them.

3. Why the touching chances the orientation of the flux tube?

If this model is on a right track, the findings would mean a direct observation of dark magnetic flux tubes by the em radiation of dark photons transformed to ordinary photons as they leak out from dark sectors of the embedding space to the sector containing the matter visible to us.

The explanation in terms of diffraction does not work

For the sake of completeness also the interpretation of the replication of the images of the instrument and DNA cell in terms of diffraction is discussed although this explanation forces several ad hoc assumptions unlike the previous model.

1. The appearance of the replicas along horizontal half-line $x > 0$ brings strongly in mind a diffraction through a vertical slit defined by a vertical dark flux sheet attached to the instrument and acting as a window. This requires coherence so that ordinary visible light cannot be responsible for the image whereas dark photons with a large enough value of Planck constant makes the quantum coherence possible.

2. The amplitude for a diffraction through slit behaves as $A = sin(x)/x$, $x = \pi \times (a/\lambda) \times sin(\theta)$, where θ is the angle between the normal of the slit and direction of observation. Hence the maxima of the intensity maxima correspond to the central maximum $\sin(\theta) = 0$ given by geometric optics and $\sin(\theta) = (n + 1/2) \times \lambda/a$ so that for small angles one has $\Delta\theta = \lambda/a$ and the distance between replicas is $x = d\Delta\theta = d\lambda/a$.

3. The distance between the replicas in the image requires a wavelength longer than used in experiments. Thus dark photons with a scaled up wavelength $\lambda = r\lambda_0$, $r = \hbar/\hbar_0$, transforming by Planck constant changing phase transition to ordinary photons in camera could be in question. The value of the Planck constant can be deduced by using the geometric data, the values of wavelength, and the distance between the replicas of instrument images assuming that diffraction effectively takes place through a vertical slit with width of order size of typical replicated instrument, say seal. From $\theta \leq D/d$, where D is the size of camera aperture, and from the number n of horizontal replicas $n < 100$ one obtains the estimate $d\lambda/a \sim D/nd$. This gives $\lambda/a \sim D/nd^2$. For $D = .01$ m, $d = .5$ m, one would have $\lambda/a \sim 4 \times 10^{-4}$. For $\lambda = 4 \times 10^{-7}$ m this would give $a \sim 10^{-3}$ m. The appearance of details in the replicated image suggest that a is of the same order than the instrument size so that one has $a \geq x > 1$ cm giving $\hbar/\hbar_0 \geq 10x$. The value of λ seems to be too small to allow coherence in the required length scale.

4. The serious problem of this interpretation is that the diffraction pattern for a diffraction through slit corresponds to maxima at an entire transversal line rather than half-line. It is as if the effective vertical flux sheet attached to the left hand side of the object would contain a distribution of horizontal dipoles generating radiation interfering to zero at the left half of the half-space. This distribution should be determined by the radiation coming from the object so that a kind of induced emission process would be in question. One can also imagine is that the dark space-time sheet along which photons arrive is half-space with horizontal coordinate $x \geq 0$. What is intriguing that in p-adic physics for which the values of variables finite in real sense are always positive as real numbers so that half-lines, quadrants, octants, ... are very natural objects. One must admit that this assumption looks ad hoc.

5. There is also a second problem. The evidence for the replication of same basic unit with the size of the DNA containing cell suggests that a replication of the image of cell containing the DNA along a curved band is in question with essentially the same distance between replicas as in the previous case. It is impossible to have a curved slit producing this kind of diffraction pattern. One could consider also the possibility that the band corresponds to a real structure, may be magnetic flux tube, and that Planck constant is now larger than in the case of instrument images so that only the central image of the diffraction pattern is visible in the camera. This however forces to ask whether also the replicas of instruments correspond to magnetic flux tubes so that one would end up with the first model.

4.5 Water Memory, Phantom DNA Effect, And Development Of TQC Hardware

This section describes speculative picture in which a connection between homeopathy and water memory [K48] with phantom DNA effect is proposed and on basis of this connection a vision about how the TQC hardware represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment.

4.5.1 A Possible Realization Of Water Memory

The Benveniste's discovery of water memory [I59, I60] initiated quite dramatic sequence of events. The original experiment involved the homeopathic treatment of water by human antigene. This meant dilution of the water solution of antigene so that the concentration of antigene became extremely low. In accordance with homeopathic teachings human basophils reacted on this solution.

The discovery was published in Nature and due to the strong polemic raised by the publication of the article, it was decided to test the experimental arrangement. The experimental results were reproduced under the original conditions. Then it was discovered that experimenters knew which bottles contained the treated water. The modified experiment in which experimenters did not possess this information failed to reproduce the results and the conclusion was regarded as obvious and Benveniste lost his laboratory among other things. Obviously any model of the effect taking it as a real effect rather than an astonishingly simplistic attempt of top scientists to cheat should explain also this finding.

The model based on the notion of field body and general mechanism of long term memory allows to explain both the memory of water and why it failed under the conditions described.

1. Also molecules have magnetic field bodies acting as intentional agents controlling the molecules. Nano-motors do not only look co-operating living creatures but are such. The field body of the molecule contains besides the static magnetic and electric parts also dynamical parts characterized by frequencies and temporal patterns of fields. To be precise, one must speak both field and relative field bodies characterizing interactions of molecules. Right brain sings-left brain talks metaphor might generalize to all scales meaning that representations based on both frequencies and temporal pulse with single frequency could be utilized.

2. The effects of complex bio-molecule to other bio-molecules (say antigene on basofil) in water could be characterized to some degree by the temporal patterns associated with the dynamical part of its field body and bio-molecules could recognize each other via these patterns. This would mean that symbolic level in interactions would be present already in the interactions of bio-molecules. Cyclotron frequencies are most natural candidates for the frequency signatures and the fact that frequencies in 10 kHz range are involved supports this view.

3. The original idea was that water molecule clusters are able to mimic the bio-molecules themselves -say their vibrational and rotational spectra could coincide with those of molecules in reasonable approximation. A more natural idea is that they can mimic their field bodies. Homeopathy could rely on extremely simple effect: water molecule clusters would steal the magnetic bodies of the molecules used to manufacture the homeopathic remedy. The shaking of the bottle containing the solution would enhance the probability for bio-molecule to lose its magnetic body in this manner. For instance, water could produce fake copies of say antigenes recognized by basofils and reacting accordingly if the reaction is based on interaction with the magnetic body of the antigene.

4. The basic objection against this picture is that it does not explain why the repeated dilution works. Rather, it seems that dilution of molecules reduces also the density of mimicking pseudo-molecules. Even more, the potency of the homeopathic remedy is claimed to increase as the dilution factor increases. Also alcohol is used instead of water so that also alcohol must allow homeopathic mechanism. (I am grateful for Ulla Matfolk for questions which made me to realize these objections).

    (a) The only way out seems to be that the magnetic bodies or water molecule clusters having these magnetic bodies can replicate. The shaking of the remedy could provide the needed metabolic energy so that the population of magnetic bodies grows to a limiting density determined by the metabolic energy feed. In principle it would be possible to infect unlimited amount of water by these pseudo-molecules. When in bottle the population would be in dormant state but in the body of the patient it would wake up and form a population of molecular actors and stimulate the immune system to develop immune response to the real molecule.

(b) The potency of the homeopathic remedy is claimed to increase with the increased dilution factor. This would suggest that the continued dilution and shaking also increases the density of pseudo molecules, perhaps by feeding to the system metabolic energy or by some other mechanism.

(c) Also magnetic bodies must replicate in cell replication and their role as intentional agents controlling bio-matter requires that this replication serves as a template for biochemical replication. On can indeed interpret the images about cell replication in terms of replication of dipole type magnetic field. This process is very simple and could have preceded biological replication. The question is therefore whether water is actually a living system in presence of a proper metabolic energy feed. Also the water's ability near critical point for freezing to form nice patterns correlating with sound stimuli might be due to the presence of the molecular actors.

(d) This picture fits nicely with the vision that evolution of water in this kind of life form might have happened separately and that pre-biotic chemical life forms have formed symbiosis with living water [K38, K39]. In the model of DNA as topological quantum computer [K3] the asymptotic self organization patterns of water flow in the vicinity of lipid layers indeed define quantum computer programs by inducing the braiding of the magnetic flux tubes connecting DNA nucleotides to lipids so that this symbiosis would have brought in new kind of information processing tool.

5. The magnetic body of the molecule could mimic the vibrational and rotational spectra using harmonics of cyclotron frequencies. Cyclotron transitions could produce dark photons, whose ordinary counterparts resulting in de-coherence would have large energies due to the large value of $\hbar$ and could thus induce vibrational and rotational transitions. This would provide a mechanism by which molecular magnetic body could control the molecule. Note that also the antigenes possibly dropped to the larger space-time sheets could produce the effect on basofils.

6. There is a considerable experimental support for the Benveniste's discovery that bio-molecules in water environment are represented by frequency patterns, and several laboratories are replicating the experiments of Benveniste as I learned from the lecture of Yolene Thomas in the 7: th European SSE Meeting held in Röros [J11]. The scale of the frequencies involved is around 10 kHz and as such does not correspond to any natural molecular frequencies. Cyclotron frequencies associated with electrons or dark ions accompanying these macromolecules would be a natural identification if one accepts the notion of molecular magnetic body. For ions the magnetic fields involved would have a magnitude of order.03 Tesla if 10 kHz corresponds to scaled up alpha band. Also Josephson frequencies would be involved if one believes that EEG has fractally scaled up variants in molecular length scales.

Consider now the argument explaining the failure to replicate the experiments of Benveniste.

1. The magnetic bodies of water molecules need metabolic energy for communications with their "biological body" using the fractally scaled analog of EEG. There is no obvious source for this energy in water. The model for protein folding and DNA as topological quantum computer assumes that magnetic flux tubes connecting subject person and target of directed attention serve as correlates for directed attention at the molecular level [K3, K7]. This should be true also in macroscopic scales so that the experimentalist and the bottle containing the treated water should be connected by magnetic flux tubes. If experimenter has directed his attention to the bottle of water, the resulting magnetic flux tubes could allow a transfer of metabolic energy as a radiation along massless extremals parallel to the flux tubes and defining TGD counterparts of Alfven waves. Experimenter's strong motivation to replicate experiments would help to realize the transfer of the metabolic energy. Experimenters not knowing, which bottles were treated did not have these flux tube bridges to the bottles, and were not able to provide the needed metabolic energy, and the magnetic bodies of antigenes failed to generate the cyclotron radiation making them visible to the basofil.

2. If this interpretation is correct, then Benveniste's experiment would demonstrate besides water memory also psychokinesis and direct action of desires of experimenters on physics at microscopic level. Furthermore, the mere fact that we know something about some object or direct attention to it would mean a concrete interaction of our magnetic body with the object. The so called phenomenon of psi track [J25] provides additional support for this conclusion.

4.5.2 Could Virtual DNAs Allow A Controlled Development Of The Genome?

The fundamental question in the evolution biology is the question about the interaction between genome (G), phenotype (P), and environment (E).

1. The standard dogma is that the information transfer from G to P is unidirectional and that environment acts on G by inducing random mutations of G, from which E selects the lucky survivors as those with the best ability to reproduce. Lamarckism [I14, I55, I61] represents a deviation from standard dogma by assuming direct information transfer from E to G.

2. Genetic expression is controlled by environment, at least by silencing [I14], which is like selecting only few books to be read from a big library. Cell differentiation represents basic example of selective gene expression. DNA methylation and transposition are accepted to reflect information transfer from E to G, perhaps via P. These modifications are believed to be short lasting and not transferred to the offspring since it is difficult to imagine a mechanism transferring the mutations to the germ cells. There is however also evidence that epigenetic information transfer takes place [I82]: this transfer would be selective expression of genes of germ cells rather than that of modified genes.

3. There are findings challenging the dogmas of static genome and random mutations. The cells of the immune system remodel their genes coding for antibodies capable of recognizing large variety of antigens. There is quite recent finding [I68] revealing major genetic differences between blood and tissue cells. There are also mutations due to jumping genes - mobile elements of DNA known as LINE-1 elements usually regarded as junk DNA whose portion from genome increases as one climbs up along the evolutionary ladder. In mice jumping genes are limited to brain and germ cells: this is easy to understand since in organs like heart and lungs this kind of mutations would be fatal. Second recent discovery is that there is a high diversity of human brain cells believed to be due to the jumping genes [I52]. That brain cells would be producing with a high rate junk DNA is not an idea which would make me shout "Eureka!"

4. The question however remains whether the $G \rightarrow P - E$ actually could complete to a closed loop $G \rightarrow P - E - G$ so that genome could directly respond to the changing physical environment and could transfer the successful response to the next generation [I55].

Could genome be developed like computer hardware?

In TGD framework the sequence $G \rightarrow P - E$ is replaced with a closed loop $G - P - M - E$ to which E is attached at P by bidirectional arrow (organisms do also modify their environment actively). Magnetic body thus controls genome and receives information from cell membrane (P). The hierarchy of genomes (super-genome, hyper-genome, ...) corresponding to the different levels of dark matter hierarchy allows this loop to be realized in different scales rather only at the level of single cell.

The question is whether the magnetic body of organism or higher level magnetic bodies could modify genomes, super-genomes, and hyper-genomes directly, perhaps by generating mutations of the genome in a short time scale; by monitoring how genetically modified organism survives in the environment; and -if the outcome of the experiment is successful - replacing the corresponding portion of DNA with the modified DNA both in ordinary germ cells. One can even ask whether the abstract model of the external environment provided by the internal chemical milieu might be mimicked by water magnetic bodies of water molecule clusters and provide a virtual world testing ground for a search of favorable mutations.

In DNA as a TQC vision essentially the development of a new computer hardware would be in question, and should take place in a controlled manner and involve an experimentation before going to the market rather than by random modifications taking place in computer CPUs. Second basic aspect of DNA as TQC paradigm is that water and bio-molecules live in symbiosis in the sense that self organization patterns of the cellular water flow define the TQC programs. The following first guess for how the development of computer hardware might be achieved is just a first guess but might have something to do with reality.

1. What would be needed is a mechanism generating rapidly modifications of DNA. The mutations should be carried out using a kind of virtual DNA mimicking all the essential aspects of the symbolic dynamics associated with DNA. The magnetic bodies of DNA consisting of flux tubes connecting the nucleotides of DNA strands to cell membrane satisfy these conditions since A, T, G, C is coded to exotic light quarks u, d and anti-quarks $\overline{u}$, $\overline{d}$ at the ends of flux tubes [K3]. DNA nucleotides could be replaced with clusters of water molecules but also other options can be imagined. Note that it does not matter when one speaks of mimicry of RNA or DNA molecules.

2. If the proposed model of the phantom DNA and homeopathy has something to do with reality, this kind of virtual DNA exists and is generated in phantom DNA effect as magnetic bodies of DNA, including of course the magnetic flux tubes connecting the nucleotides to the cell membrane or conjugate strand of DNA.

3. The crucial additional assumption would be that also the reversal of phantom DNA effect is possible and corresponds to the analog of DNA replication in which nucleotides attach to the virtual conjugate nucleotides of the virtual DNA strand or RNA strand in turn transformed to DNA strand be reverse transcription. The hypothesis would have rather strong implications for the genetic engineering since homeopathic remedies of genetically engineered DNA sequences could be transferred to cell nuclei just by drinking them.

4. Phantom DNA sequences could form populations and - as far as their properties as a hardware of topological quantum computer are involved - evolve under selection pressures of the virtual world defined by the nuclear, cellular and extracellular water. A competition of components of TQC hardware developed by the higher level magnetic body to realize optimally TQC programs needed for survival would be in question. The simplest mutation of phantom DNA would replace the quark pairs at the ends the (wormhole-) magnetic flux tube with a new one and could occur in very short time scale. Also basic editing operations like cutting and pasting would be possible for these competing phantom DNA sequences. The winners in the competition would be transformed to actual DNA sequences by utilizing the reverse phantom DNA (or RNA -) effect and be inserted to genome. The genetic machinery performing cutting, gluing, and pasting of real DNA in a controlled manner exists. What is needed is the machinery monitoring who is the winner and making the decision to initiate the modification of the real DNA.

5. The transfer of the mutations to germ cells could be achieved by allowing the population of the virtual DNA sequences to infect the water inside germ cells. The genetic program inducing the modification of DNA by using the winner of the TQC hardware competition should run automatically.

6. One open question is whether the nuclear, cellular or perhaps also extracellular water should represent the physical environment and - if answer is affirmative - how it achieves this. As a matter fact, considerable fraction of water inside cells is in gel phase and it might be that the intercellular water, which naturally defines a symbolic representation of environment, is where the virtual evolution takes place. Internal chemical milieu certainly reflects in an abstract manner the physical environment and the ability of the water molecule clusters to mimic bio-molecules would make the representation of the chemical environment possible. Also sudden changes of external milieu would be rapidly coded to the changes in internal milieu which might help to achieve genetic re-organization. The craziest dream is water based simulation of both genes, proteins, and molecules representing external world running at dark space-time sheets.

Dark nuclear strings as analogs of DNA-, RNA- and amino-acid sequences and baryonic realization of genetic code?

The minimal option is that virtual DNA sequences have flux tube connections to the lipids of the cell membrane so that their quality as hardware of TQC can be tested but that there is no virtual variant of transcription and translation machinery. One can however ask whether also virtual amino-acids could be present and whether this could provide deeper insights to the genetic code.

1. Water molecule clusters are not the only candidates for the representatives of linear molecules. An alternative candidate for the virtual variants of linear bio-molecules are dark nuclei consisting of strings of scaled up dark variants of neutral baryons bound together by color bonds having the size scale of atom, which I have introduced in the model of cold fusion and plasma electrolysis both taking place in water environment [L1], [L1]. Colored flux tubes defining braidings would generalize this picture by allowing transversal color magnetic flux tube connections between these strings.

2. This seems to work! The states of dark nucleons formed from three quarks can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, and 20 amino-acids and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

The basic idea is simple. Since baryons consist of 3 quarks just as DNA codons consist of three nucleotides, one might ask whether codons could correspond to baryons obtained as open strings with quarks connected by two color flux tubes. This representation would be based on entanglement rather than letter sequences. The question is therefore whether the dark baryons constructed as string of 3 quarks using color flux tubes could realize 64 codons and whether 20 amino-acids could be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner.

The following model indeed reproduces the genetic code directly from a model of dark neutral baryons as strings of 3 quarks connected by color flux tubes.

1. Dark nuclear baryons are considered as a fundamental realization of DNA codons and constructed as open strings of 3 dark quarks connected by two colored flux tubes, which can be also charged. The baryonic strings cannot combine to form a strictly linear structure since strict rotational invariance would not allow the quark strings to have angular momentum with respect to the quantization axis defined by the nuclear string. The independent rotation of quark strings and breaking of rotational symmetry from SO(3) to SO(2) induced by the direction of the nuclear string is essential for the model.

   (a) Baryonic strings could form a helical nuclear string (stability might require this) locally parallel to DNA, RNA, or amino-acid) helix with rotations acting either along the axis of the DNA or along the local axis of DNA along helix. The rotation of a flux tube portion around an axis parallel to the local axis along DNA helix requires that magnetic flux tube has a kink in this portion. An interesting question is whether this kink has correlate at the level of DNA too. Notice that color bonds appear in two scales corresponding to these two strings. The model of DNA as topological quantum computer [K3] allows a modification in which dark nuclear string of this kind is parallel to DNA and each codon has a flux tube connection to the lipid of cell membrane or possibly to some other bio-molecule.

   (b) The analogs of DNA -, RNA -, and of amino-acid sequences could also correspond to sequences of dark baryons in which baryons would be 3-quark strings in the plane transversal to the dark nuclear string and expected to rotate by stringy boundary conditions. In this case all dark baryons would be free to rotate. Thus one would have nuclear string consisting of short baryonic strings not connected along their ends.

2. The new element as compared to the standard quark model is that between both dark quarks and dark baryons can be charged carrying charge $0, \pm 1$. This is assumed also in nuclear string

model and there is empirical support for the existence of exotic nuclei containing charged color bonds between nuclei.

3. The net charge of the dark baryons in question is assumed to vanish to minimize Coulomb repulsion:

$$\sum_q Q_{em}(q) = -\sum_{flux\ tubes} Q_{em}(flux\ tube)\ . \tag{4.5.1}$$

This kind of selection is natural taking into account the breaking of isospin symmetry. In the recent case the breaking cannot however be as large as for ordinary baryons (implying large mass difference between Δ and nucleon states).

4. One can classify the states of the open 3-quark string by the total charges and spins associated with 3 quarks and to the two color bonds. Total em charges of quarks vary in the range $Z_B \in \{2,1,0,-1\}$ and total color bond charges in the range $Z_b \in \{2,1,0,-1,-2\}$. Only neutral states are allowed. Total quark spin projection varies in the range $J_B = 3/2, 1/2, -1/2, -3/2$ and the total flux tube spin projection in the range $J_b = 2, 1, -1, -2$. If one takes for a given total charge assumed to be vanishing one representative from each class (J_B, J_b), one obtains $4 \times 5 = 20$ states which is the number of amino-acids. Thus genetic code might be realized at the level of baryons by mapping the neutral states with a given spin projection to single representative state with the same spin projection. The problem is to find whether one can identify the analogs of DNA, RNA and amino-acids as baryon like states.

1. States in the quark degrees of freedom

One must construct many-particle states both in quark and flux tube degrees of freedom. These states can be constructed as representations of rotation group SU(2) and strong isospin group SU(2) by using the standard tensor product rule $j_1 \times j_2 = j_1 + j_2 \oplus j_1 + j_2 - 1 \oplus ... \oplus |j_1 - j_2|$ for the representation of SU(2) and Fermi statistics and Bose-Einstein statistics are used to deduce correlations between total spin and total isospin (for instance, $J = I$ rule holds true in quark degrees of freedom). Charge neutrality is assumed and the breaking of rotational symmetry in the direction of nuclear string is assumed.

Consider first the states of dark baryons in quark degrees of freedom.

1. The tensor product $2 \otimes 2 \otimes 2$ is involved in both cases. Without any additional constraints this tensor product decomposes as $(3 \oplus 1) \otimes 2 = 4 \oplus 2 \oplus 2$: 8 states altogether. This is what one should have for DNA and RNA candidates. If one has only identical quarks uuu or ddd, Pauli exclusion rule allows only the 4-D spin 3/2 representation corresponding to completely symmetric representation -just as in standard quark model. These 4 states correspond to a candidate for amino-acids. Thus RNA and DNA should correspond to states of type uud and ddu and amino-acids to states of type uuu or ddd. What this means physically will be considered later.

2. Due to spin-statistics constraint only the representations with $(J, I) = (3/2, 3/2)$ (Δ resonance) and the second $(J, I) = (1/2, 1/2)$ (proton and neutron) are realized as free baryons. Now of course a dark -possibly p-adically scaled up - variant of QCD is considered so that more general baryonic states are possible. By the way, the spin statistics problem which forced to introduce quark color strongly suggests that the construction of the codons as sequences of 3 nucleons - which one might also consider - is not a good idea.

3. Second nucleon like spin doublet - call it 2_{odd} - has wrong parity in the sense that it would require $L = 1$ ground state for two identical quarks (uu or dd pair). Dropping 2_{odd} and using only $4 \oplus 2$ for the rotation group would give degeneracies $(1, 2, 2, 1)$ and 6 states only. All the representations in $4 \oplus 2 \oplus 2_{odd}$ are needed to get 8 states with a given quark charge and one should transform the wrong parity doublet to positive parity doublet somehow. Since open string geometry breaks rotational symmetry to a subgroup SO(2) of rotations acting

along the direction of the string and since the boundary conditions on baryonic strings force their ends to rotate with light velocity, the attractive possibility is to add a baryonic stringy excitation with angular momentum projection $L_z = -1$ to the wrong parity doublet so that the parity comes out correctly. $L_z = -1$ orbital angular momentum for the relative motion of uu or dd quark pair in the open 3-quark string would be in question. The degeneracies for spin projection value $J_z = 3/2, ..., -3/2$ are $(1, 2, 3, 2)$. Genetic code means spin projection mapping the states in $4 \oplus 2 \oplus 2_{odd}$ to 4.

2. States in the flux tube degrees of freedom

Consider next the states in flux tube degrees of freedom.

1. The situation is analogous to a construction of mesons from quarks and antiquarks and one obtains the analogs of π meson (pion) with spin 0 and ρ meson with spin 1 since spin statistics forces $J = I$ condition also now. States of a given charge for a flux tube correspond to the tensor product $2 \otimes 2 = 3 \oplus 1$ for the rotation group.

2. Without any further constraints the tensor product $3 \otimes 3 = 5 \oplus 3 \oplus 1$ for the flux tubes states gives 8+1 states. By dropping the scalar state this gives 8 states required by DNA and RNA analogs. The degeneracies of the states for DNA/RNA type realization with a given spin projection for $5 \oplus 3$ are $(1, 2, 2, 2, 1)$. $8\times$ 8 states result altogether for both uud and udd for which color bonds have different charges. Also for ddd state with quark charge -1 one obtains $5 \oplus 3$ states giving 40 states altogether.

3. If the charges of the color bonds are identical as the are for uuu type states serving as candidates for the counterparts of amino-acids bosonic statistics allows only 5 states ($J = 2$ state). Hence 20 counterparts of amino-acids are obtained for uuu. Genetic code means the projection of the states of $5 \oplus 3$ to those of 5 with the same spin projection and same total charge.

3. Analogs of DNA, RNA, amino-acids, and of translation and transcription mechanisms

Consider next the identification of analogs of DNA, RNA and amino-acids and the baryonic realization of the genetic code, translation and transcription.

1. The analogs of DNA and RNA can be identified dark baryons with quark content uud, ddu with color bonds having different charges. There are 3 color bond pairs corresponding to charge pairs $(q_1, q_2) = (-1, 0), (-1, 1), (0, 1)$ (the order of charges does not matter). The condition that the total charge of dark baryon vanishes allows for uud only the bond pair $(-1, 0)$ and for udd only the pair $(-1, 1)$. These thus only single neutral dark baryon of type *uud resp. udd*: these would be the analogous of DNA and RNA codons. Amino-acids would correspond to uuu states with identical color bonds with charges $(-1, -1)$, $(0, 0)$, or $(1, 1)$. uuu with color bond charges (-1, -1) is the only neutral state. Hence only the analogs of DNA, RNA, and amino-acids are obtained, which is rather remarkable result.

2. The basic transcription and translation machinery could be realized as processes in which the analog of DNA can replicate, and can be transcribed to the analog of mRNA in turn translated to the analogs of amino-acids. In terms of flux tube connections the realization of genetic code, transcription, and translation, would mean that only dark baryons with same total quark spin and same total color bond spin can be connected by flux tubes. Charges are of course identical since they vanish.

3. Genetic code maps of $(4 \oplus 2 \oplus 2) \otimes (5 \oplus 3)$ to the states of 4×5. The most natural map takes the states with a given spin to a state with the same spin so that the code is unique. This would give the degeneracies $D(k)$ as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies $D = 1, 2, 3, 4, 6$ are predicted. The numbers $N(k)$ of amino-acids coded by D codons would be

$$[N(1), N(2), N(3), N(4), N(6)] = [2, 7, 2, 6, 3] \ .$$

The correct numbers for vertebrate nuclear code are $(N(1), N(2), N(3), N(4), N(6)) = (2, 9, 1, 5, 3)$. Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result $(2, 9, 1, 5, 3)$!

4. Stopping codons would most naturally correspond to the codons, which involve the $L_z = -1$ relative rotational excitation of uu or dd type quark pair. For the 3-plet the two candidates for the stopping codon state are $|1/2, -1/2\rangle \otimes \{|2, k\rangle\}$, $k = 2, -2$. The total spins are $J_z = 3/2$ and $J_z = -7/2$. The three candidates for the 4-plet from which two states are thrown out are $|1/2, -3/2\rangle \otimes \{|2, k\rangle, |1, k\rangle\}$, $k = 1, 0, -1$. The total spins are now $J_z = -1/2, -3/2, -5/2$. One guess is that the states with smallest value of J_z are dropped which would mean that $J_z = -7/2$ states in 3-plet and $J_z = -5/2$ states 4-plet become stopping codons.

5. One can ask why just vertebrate code? Why not vertebrate mitochondrial code, which has unbroken $A - G$ and $T - C$ symmetries with respect to the third nucleotide. And is it possible to understand the rarely occurring variants of the genetic code in this framework? One explanation is that the baryonic realization is the fundamental one and biochemical realization has gradually evolved from non-faithful realization to a faithful one as kind of emulation of dark nuclear physics. Also the role of tRNA in the realization of the code is crucial and could explain the fact that the code can be context sensitive for some codons.

4. Understanding the symmetries of the code

Quantum entanglement between quarks and color flux tubes would be essential for the baryonic realization of the genetic code whereas chemical realization could be said to be classical. Quantal aspect means that one cannot decompose to codon to letters anymore. This raises questions concerning the symmetries of the code.

1. What is the counterpart for the conjugation $ZYZ \rightarrow X_cY_cZ_c$ for the codons?

2. The conjugation of the second nucleotide Y having chemical interpretation in terms of hydrophobia-hydrophily dichotomy in biology. In DNA as TQC model it corresponds to matter-antimatter conjugation for quarks associated with flux tubes connecting DNA nucleotides to the lipids of the cell membrane. What is the interpretation in now?

3. The A-G, T-C symmetries with respect to the third nucleotide Z allow an interpretation as weak isospin symmetry in DNA as TQC model. Can one identify counterpart of this symmetry when the decomposition into individual nucleotides does not make sense?

Natural candidates for the building blocks of the analogs of these symmetries are the change of the sign of the spin direction for quarks and for flux tubes.

1. For quarks the spin projections are always non-vanishing so that the map has no fixed points. For flux tube spin the states of spin $S_z = 0$ are fixed points. The change of the sign of quark spin projection must therefore be present for both $XYZ \rightarrow X_cY_cZ_c$ and $Y \rightarrow Y_c$ but also something else might be needed. Note that without the symmetry breaking $(1, 3, 3, 1) \rightarrow (1, 2, 3, 2)$ the code table would be symmetric in the permutation of 2 first and 2 last columns of the code table induced by both full conjugation and conjugation of Y.

2. The analogs of the approximate $A - G$ and $T - C$ symmetries cannot involve the change of spin direction in neither quark nor flux tube sector. These symmetries act inside the A-G and T-C sub-2-columns of the 4-columns defining the rows of the code table. Hence this symmetry must permute the states of same spin inside 5 and 3 for flux tubes and 4 and 2 for quarks but leave 2_{odd} invariant. This guarantees that for the two non-degenerate codons coding for only single amino-acid and one of the codons inside triplet the action is trivial. Hence the baryonic analog of the approximate $A - G$ and $T - C$ symmetry would be exact symmetry and be due to the basic definition of the genetic code as a mapping states of same flux tube spin and quark spin to single representative state. The existence of full 4-columns coding for the same amino-acid would be due to the fact that states with same quark spin inside $(2, 3, 2)$ code for the same amino-acid.

3. A detailed comparison of the code table with the code table in spin representation should allow to fix their correspondence uniquely apart from permutations of n-plets and thus also the representation of the conjugations. What is clear that Y conjugation must involve the change of quark spin direction whereas Z conjugation which maps typically 2-plets to each other must involve the permutation of states with same J_z for the flux tubes. It is not quite clear what X conjugation correspond to.

5. Some comments about the physics behind the code

Consider next some particle physicist's objections against this picture.

1. The realization of the code requires the dark scaled variants of spin 3/2 baryons known as Δ resonance and the analogs (and only the analogs) of spin 1 mesons known as ρ mesons. The lifetime of these states is very short in ordinary hadron physics. Now one has a scaled up variant of hadron physics: possibly in both dark and p-adic senses with latter allowing arbitrarily small overall mass scales. Hence the lifetimes of states can be scaled up.

2. Both the absolute and relative mass differences between Δ and N *resp.* ρ and π are large in ordinary hadron physics and this makes the decays of Δ and ρ possible kinematically. This is due to color magnetic spin-spin splitting proportional to the color coupling strength $\alpha_s \sim .1$, which is large. In the recent case α_s could be considerably smaller - say of the same order of magnitude as fine structure constant 1/137 - so that the mass splittings could be so small as to make decays impossible.

3. Dark hadrons could have lower mass scale than the ordinary ones if scaled up variants of quarks in p-adic sense are in question. Note that the model for cold fusion that inspired the idea about genetic code requires that dark nuclear strings have the same mass scale as ordinary baryons. In any case, the most general option inspired by the vision about hierarchy of conscious entities extended to a hierarchy of life forms is that several dark and p-adic scaled up variants of baryons realizing genetic code are possible.

4. The heaviest objection relates to the addition of $L_z = -1$ excitation to $S_z = |1/2, \pm 1/2\rangle_{odd}$ states which transforms the degeneracies of the quark spin states from $(1, 3, 3, 1)$ to $(1, 2, 3, 2)$. The only reasonable answer is that the breaking of the full rotation symmetry reduces $SO(3)$ to $SO(2)$. Also the fact that the states of massless particles are labeled by the representation of $SO(2)$ might be of some relevance. The deeper level explanation in TGD framework might be as follows. The generalized embedding space is constructed by gluing almost copies of the 8-D embedding space with different Planck constants together along a 4-D subspace like pages of book along a common back. The construction involves symmetry breaking in both rotational and color degrees of freedom to Cartan sub-group and the interpretation is as a geometric representation for the selection of the quantization axis. Quantum TGD is indeed meant to be a geometrization of the entire quantum physics as a physics of the classical spinor fields in the "world of classical worlds" so that also the choice of measurement axis must have a geometric description.

The conclusion is that genetic code can be understand as a map of stringy baryonic states induced by the projection of all states with same spin projection to a representative state with the same spin projection. Genetic code would be realized at the level of dark nuclear physics and biochemical representation would be only one particular higher level representation of the code. A hierarchy of dark baryon realizations corresponding to p-adic and dark matter hierarchies can be considered. Translation and transcription machinery would be realized by flux tubes connecting only states with same quark spin and flux tube spin. Charge neutrality is essential for having only the analogs of DNA, RNA and amino-acids and would guarantee the em stability of the states.

Crying and screaming cells and magnetic bodies expressing their emotions

By using nanotechnological methods James Gimzewski [J1], his student Andrew Pelling and collaborators discovered that the cell walls of bacterium Saccharomyces cerevisiae perform periodic motion with amplitude about 3 nm in the frequency range.8-1.6 kHz (one octave) [I69]. Or more concretely, bacteria produce sounds audible to humans with average frequency of 1 kHz in a range of one octave. The frequency has strong temperature dependence, which suggests a metabolic mechanism. From the temperature dependence one deduces the activation energy to be 58 kJ/mol, which is consistent with the cell's metabolism involving molecular motors such as kinesin, dynein, and myosin. The magnitude of the forces observed (10 nN) suggests concerted nanomechanical activity is operative in the cell.

From less formal popular articles [I56] one can learn that it is difficult to avoid the impression that intelligent communication is in question. Dying cells produce a characteristic screaming sound. One can also distinguish between normal cells and cancel cells on basis of the sound they produces as well as between mammalian and bacterial cells.

What might be the explanation of these findings in TGD framework?

1. It is known that the region of frequencies audible to human ear is from about 20 Hz to 2×10^4 Hz. This is more or less same as the range of frequency range of sferics, the em noise in atmosphere [F1]. This suggests a strong coupling between electromagnetic oscillations and sound as also the fact that biological structures are piezo-electrets transforming em oscillations to sounds and vice versa.

2. The activation energy per mole corresponds to.6 eV per molecule which is at the upper range for the variation range the energy associated with the fundamental metabolic energy quantum identified as the change of zero point kinetic as proton is transferred from atomic space-time sheet to much larger space-time sheet or vice versa.That metabolic energy is needed to produce the sounds supports the view that the sounds are produced intentionally.

3. If one takes seriously the notion of magnetic body as intentional agent controlling biological body, one is led to ask which must sound a totally crazy question in reductionistic ears: could magnetic body express its emotions in terms of frequencies of cyclotron transitions transformed to sound via genetic expression using piezo electric mechanism? Could it be that the photons involved are dark photons with large value of Planck constant so that their energy is above thermal energy. Could one propose a materialistic scientist to consider anything more irritating that singing and crying magnetic bodies!

4. Suppose that the homeopathic mechanism is based on replication of pseudo-molecules with same magnetic body as that of solvent molecules and that neutral dark nuclear strings realize analogs of DNA, RNA, and amino-acids and realizing genetic code exactly in its vertebrate nuclear form and appearing also in the TGD based model of cold fusion and biological transmutations. If so, then homeopathic mechanism (recognition of molecules) could involve also the transformation of cyclotron radiation to sound at the level of "biological bodies" of molecules.

5. If this picture makes sense then also our speech as a self expression of the magnetic body might involve genetic code mapping sequences of DNA codons to temporal patterns of cyclotron radiation in turn transformed to speech by above mechanism. This would require a realization of genetic code at level of dark matter: could it be that dark nuclear code could define universal quantum level realization of language? The findings of Peter Gariaev and others and structural resemblance of intronic portion of genome with language and their report that DNA sequences are coded to temporal patterns of the rotation angle of the polarization of laser light (in turn inducing genetic expression).

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Chapter 5

Holography and Quantum Error Correcting Codes: TGD View

5.1 Introduction

Strong form of holography is one of the basic tenets of TGD, and I have been working with topological quantum computation in TGD framework with the braiding of magnetic flux tubes defining the space-time correlates for topological quantum computer programs [K3]. Flux tubes are accompanied by fermionic strings, which can become braided too and would actually represent the braiding at fundamental level. Also time like braiding of fermionic lines at light-like 3-surfaces and the braiding of light-like 3-surfaces themselvs is involved and one can talk about space-like and time-like braidings. These two are not independent being related by dance metaphor (think dancers at the parquette connected by threads to a wall generating both time like and space-like braidings). I have proposed that DNA and the lipids at cell membrane are connected by braided flux tubes such that the flow of lipids in lipid layer forming liquid crystal would induce braiding storing neural events to memory realized as braiding.

I have a rather limited understanding about error correcting codes. Therefore I was happy to learn that there is a conference in Stanford in which leading gurus of quantum gravity and quantum information sciences are talking about these topics. The first lecture that I listened was about a possible connection between holography and quantum error correcting codes. The lecturer was Preskill and the title of the talk was "Holographic quantum error-correcting codes: Toy models for the bulk/boundary correspondence" (see `https://www.youtube.com/watch?v=SW2rlQVfnK0` and `http://tinyurl.com/z8fsfh8`). A detailed representation can be found in the article of Preskill *et al* [B25] (see `http://arxiv.org/pdf/1503.06237.pdf`).

The idea is that time= constant section of AdS, which is hyperbolic space allowing tessellations, can define tensor networks. So called perfect tensors are building bricks of the tensor networks providing representation for holography. There are three observations that put bells ringing and actually motivated this article.

1. Perfect tensors define entanglement which TGD framework corresponds negentropic entanglement playing key role in TGD inspired theory of consciousness and of living matter.

2. In TGD framework the hyperbolic tesselations are realized at hyperbolic spaces $H_3(a)$ defining light-cone proper time hyperboloids of M^4 light-cone.

3. TGD replaces AdS/CFT correspondence with strong form of holography.

5.1.1 Could one replace AdS/CFT correspondence with TGD version of holography?

One can criticize AdS/CFT based holography because it has Minkowski space only as a rather non-unique conformal boundary resulting from conformal compactification. Situation gets worse as one starts to modify AdS by populating it with blackholes. And even this is not enough: one can imagine anything inside blackhole interiors: wormholes connecting them to other blackholes, anything. Entire mythology of mystic creatures filling the white (or actually black) areas of the map. Post-modernistic sloppiness is the problem of recent day theoretical physics - everything goes - and this leads to inflationary story telling. Minimalism would be badly needed.

AdS/CFT is very probably mathematically correct. The question is whether the underlying conformal symmetry - certainly already huge - is large enough and whether its proper extension could allow to get rid of admittedly artificial features of AdS/CFT.

In TGD framework conformal symmetries are generalized thanks due to the metric 2-dimensionality of light-cone boundary and of light-like 3-surfaces in general. The resulting generalization of Kac-Moody group as super-symplectic group replaces finite-dimensional Lie group with infinite-dimensional group of symplectic transformations and leads to what I call strong form of holography in which AdS is replaced with 4-D space-time surface and Minkowski space with 2-D partonic 2-surfaces and their light-like orbits defining the boundary between Euclidian and Minkowskian space-time regions: this is very much like ordinary holography. Also embedding space $M^4 \times CP_2$ fixed uniquely by twistorial considerations plays an important role in the holography.

AdS/CFT realization of holography is therefore not absolutely essential. Even better, its generalization to TGD involves no fictitious boundaries and is free of problems posed by closed time-like geodesics.

5.1.2 Perfect tensors and tensor networks realized in terms of magnetic body carrying negentropically entangled dark matter

Preskill *et al* suggest a *representation* of holography in terms of tensor networks associated with the tesselations of hyperbolic space and utilizing perfect tensors defining what I call negentropic entanglement. Also Minkowski space light-cone has hyperbolic space as proper time=constant section (light-cone proper time constant section in TGD) so that the model for the tensor network realization of holography cannot be distinguished from TGD variant, which does not need AdS at all.

The interpretational problem is that one obtains also states in which interior local states are non-trivial and are mapped by holography to boundary states are: holography in the standard sense should exclude these states. In TGD this problem disappears since the macroscopic surface is replaced with what I call wormhole throat (something different as GRT wormhole throat for which magnetic flux tube is TGD counterpart) can be also microscopic.

5.1.3 Physics of living matter as physics condensed dark matter at magnetic bodies?

A very attractive idea is that in living matter magnetic flux tube networks defining quantum computational networks provide realization of tensor networks realizing also holographic error correction mechanism: negentropic entanglement - perfect tensors - would be the key element! As I have proposed, these flux tube networks would define kind of central nervous system make it possible for living matter to experience consciously its biological body using magnetic body.

These networks would also give rise to the counterpart of condensed matter physics of dark matter at the level of magnetic body: the replacement of lattices based on subgroups of translation group with infinite number of tesselations means that this analog of condensed matter physics describes quantum complexity.

I am just a novice in the field of quantum error correction (and probably remain such) but from experience I know that the best way to learn something new is to tell the story with your own words. Of course, I am not at all sure whether this story helps anyone to grasp the new ideas. In any case, if one have a new vision about physical world, the situation becomes considerably easier since creative elements enter to this story re-telling. How these new ideas could be realized in the theory world? This question I try to answer in the following.

The goal in the sequel is therefore an attempt to formulate the connection between quantum holography and error correcting codes in TGD framework bringing in new features relating to the new views about space-time, quantum theory, and living matter and consciousness in relation to quantum physics.

5.2 Holography

In the following I summarize my understanding about holography.

5.2.1 Holographies

Holography has become a key notion in attempts to understand gauge theories and gravity. One variant of holography suggests that blackhole horizons containg the information about quantum state assignable to blackhole. The naïve picture is that area unit defined by Planck length corresponds to single bit.

There is also second form of holography. AdS/CFT correspondence states that conformal field theory at the boundary of $AdS_n \times S^{10-n}$ is dual to a string theory or gravitational theory in 10-dimensional space. AdS_n has Minkowski space as $n-1$ dimensional boundary and for conformal field theory in 4-D Minkowski space one would have AdS_5. AdS_n is Minkowski space with 2 time like dimensions realized as a surface $t_1^2+t_2^2-x_1^2-x_2^2-x_3^2-x_4^2 = R^2$, where R is radius of curvature.

I cannot avoid some nitpicking.

1. AdS is somewhat problematic physically since it has closed time-like geodesics as is rather clear from the defining condition (see `http://tinyurl.com/h7xltde`) and also from the $(1, 1, -1, -1, -1)$ signature of the metric. The second problem with AdS is that it is rather formal construct.

2. One speaks also about AdS boundary. AdS does not however have an actual boundary. A more precise term is conformal boundary resulting in conformal compactification transforming the metric to Minkowski metric apart from conformal factor. This transformation is fixed apart from a conformal transformation of AdS. The existence of the transformation follows from the conformal flatness of AdS which for dimensions not smaller than four can be formulated in terms of the vanishing of Weyl tensor (see `http://tinyurl.com/y7fsnzk8`). Every manifold with constant sectional curvature is conformally flat. Note that CP_2 is not conformally flat.

   Conformal boundary corresponds to vanishing value of z in the representation of $ds^2 = (ds^2(M^{n-1}) + dz^2)/z^2$ with $z > 0$ giving the half-space and $z = 0$ the $n-1$-D Minkowski space. The metric as making explicit the conformal flatness of AdS, where $\Omega^2 = 1/z^2$ is the conformal scaling factor which becomes infinite in subspace, which is Minkowski space. A second kind of singular behavior would be vanishing of Ω^2 ($z = \infty$) and also this subspace could be identified as conformal boundary.

   Conformal compactification is a map of original space with the property that it performs conformal scaling for the metric tensor. Conformal compactification requires finding of a coordinate transformation taking the metric to the desired form. Note that in the case of Minkowski space with spherical coordinates with metric $dt^2 - dr^2 - r^2 d\Omega^2$ the conformal compactification is induced by the compactifying conformal mapping of $(t, r) \to (T, R)$ satisfying therefore $g_{TT} = -g_{RR} = \Omega^2$ and $r^2 = \Omega^2 R^2$. The map can be explicitly constructed and maps (t, r) plane to a triangle. Ω^2 vanishes or diverges at the conformal boundary. This can be done also for AdS so that the resulting conformal boundary is Minkowski space and has Minkowski metric with vanishing scale factor.

   To my humble opinion, procedures of this kind should be avoided in fundamental theory. On the other hand, the twistor space of Minkowski space used in twistorialization is also conformal compactification. In this case one however has what is known as double fibration [B48] (see `http://tinyurl.com/yb4bt74l`) meaning that one has fibration from $M^4 \times S^2$ - the trivial S^2 bundle defining the geometric twistor space to the twistors space identified as complex projective space defining conformal compactification of M^4. Double fibration is essential in the twistorialization of TGD [K41].

3. Even worse - to my opinion - is that people are not happy with AdS as such but add to AdS all kinds of stuff such as blackholes making varying assumptions about their interiors. This leads easily to an inflation of sloppily defined notions. Just this happened in super string theory and eventually led to the multiverse mania. Eventually the proposal emerged that

the requirement that physical theories should be able to predict something should be given up since the exceptional "beauty" of some of these baroque constructions would be enough to justify them as the only possible theory of everything.

In TGD framework AdS/CFT correspondence is replaced with the strong form of holography.

1. Ordinary holography would state that preferred 3-surfaces - either space-time 3-surfaces at the boundaries of CD or light-like 3-surfaces connecting them - carry same quantum information as space-time surface. Strong form of holography (SH) follows from the conditions that these two identifications of 3-surfaces are equivalent and says that 2-D partonic 2-surfaces and string world sheets carry the quantal information. SHS is very similar to ordinary holography and to e blackhole holography.

   There is no need for conformal compactification and conformal boundary since boundary is something very real being identified as the light-like orbit of partonic 2-surfaces defining the boundary between Euclidian and Minkowskian space-time regions. 4-D space-time surface replaces the 10-D bulk of AdS/CFT correspondence and partonic 2-surfaces and their light-like orbits replace the space-time at boundary of AdS, where one has conformal quantum field theory (CFT).

   In analogy with conformal boundary, 4-D space-time metric becomes singular (determinant vanishes) at the light-like orbits of wormhole throats meaning that the dimension of tangent space degenerates to 4 to 3. These objects are not fictive but completely physical and can be seen as analogs of blackhole horizons making sense as analogs of boundaries for objects of any size. The new element is that the interior has Euclidian signature of induced metric and is interpreted as geometric counterpart for the line of generalized Feynman diagram or twistor diagram representing the orbit of particle [K41].

2. Classical holography means that space-time surfaces can be constructed as continuations of string world sheets and partonic 2-surfaces (and possibly also their light-like orbits giving rise to discrete number of non-gauge degrees of freedom) serving as space-time genes. Space-time surfaces are thus preferred extremals of the basic action principle. The preferred extremals would be thus 2-dimensional in information theoretic sense.

   This boils down to the condition that a sub-algebra super-symplectic algebra isomorphic to the algebra itself annihilates the physical states and that the classical Noether charges for the sub-algebra vanish. This huge number of conditions makes space-time surfaces as preferred extremals analogous to Bohr orbits. This picture leads also to the hierarchy of Planck constants $h_{eff} = n \times h$ assignable to the fractal hierarchy of isomorphic subalgebras of the super-symplectic and other conformal algebars. This implies a generalization of quantum theory crucial for biology and quantum computation since large value of h_{eff} means macroscopic quantum coherence.

3. Conformal invariance is extended dramatically and the Lie group defining Kac-Moody group becomes the symplectic group of $\delta M^4_\pm \times CP_2$, $\delta M^4_\pm$ denotes light-cone boundary. The light-like radial coordinate of light-cone boundary takes the role of additional complex coordinate z. Note that the conformal invariance is really huge at the fundamental level. This is what allows to replaced the 10-dimensional space of AdS/CFT with 4-D space-time surface and make the holography free of non-physical auxiliary constructs.

   There is also second difference: embedding space $H = M^4 \times CP_2$ - unique by twistorial considerations - enters into the game too and is expected to take some roles of AdS at the level of embedding space. The hyperbolic character of time=constant sections together with the findings of Preskill *et al* [B25] suggests how this might happen. This will be the main theme of this article.

4. In AdS-CFT correspondence radial direction from boundary is interpreted as renormalization scale. I have considered analogous interpretation for the direction normal to the partonic 2-surfaces in TGD: the idea was that any light-like 3-surface in the slicing by light-like 3-surfaces "parallel" to the orbit of partonic 3-surface is physically equivalent representation for holography. An alternative and perhaps more plausible interpretation is that RG scale

corresponds to the proper-time for light-cone boundary labelling the slices $H_3(a)$. It could also naturally correspond to the size scale of CD, perhaps the value of a for which the size of the tessellation contained by CD is largest.

Quantum criticality is basic aspects of quantum TGD and predicts that various coupling strengths have a spectrum of critical values labelled by the p-adic primes $p \simeq 2^k$, k prime: an attractive conjecture is that their values relate in simple manner to the zeros of Riemann zeta [K35]. These length scales in turn would relate to the size scales of CDs. Coupling constant evolution would become discrete. Perhaps one could interpret the preferred role of the boundaries between Minkowskian and Euclidian regions as counterpart for fixed point property of critical values of coupling constants under RG evolution.

5.2.2 Blackholes and wormholes

The many-sheeted space-time distinguishes TGD from GRT. GRT is obtained from TGD as an approximation in which the sheets are replaced by single region of Minkowski space with deformed metric obtained by adding the deviations of the metrics of the sheets with their sum representing the deviation of the metric from Minkowski metric. Components of spinor connection are added in the same manner to obtain electroweak gauge fields of the standard model. Classical color gauge potentials are identified as projections of color Killing vector fields and siimlar description applies to them. This picture follows by considering test particle as a small surface having topological contacts with various sheets of the many-sheeted space-time: the classical forces experienced by it are sums over contributions from various sheets.

Blackholes and wormholes are basic notion of GRT and they have also TGD counterparts.

1. Blackholes play akey role in the attempts to relate quantum gravity, holography, and quantum information theory in GRT framework. I am happy to see that theoreticians like Susskind (see `http://tinyurl.com/y927h695`) have the courage to imagine freely. From my own experience there is of course a risk that this leads to endless loose speculations getting us nowhere. To me blackhole interior represents the failure of GRT and the new theory must replace it with something less singular.

   In TGD framework blackholes are not fundamental and the Euclidian space-time regions with 4-D CP_2 projection representing orbits of wormhole contacts between to space-time sheets replace them. Wormhole contacts become basic building bricks of elementary particles and simplest elementary particles consist of a pair of wormhole contacts with magnetic monopole flux flowing from throat to the other one, through contact to second space-time sheet and back.

   These Euclidian regions define the analogs of lines of Feynman diagrams, and one can speak of generalized Feynman (or twistor-) diagrams represented at the level of space-time geometry and topology. There is no need to perform Wick rotation to get well-defined path integral: Euclidian regions provide to the vacuum functional automatically the real exponent guaranteing the mathematical existence of the functional integral.

2. Wormhole is second key notion of GRT. ER-EPR correspondence is a proposal that wormhole throats - kind of flux tubes between distant regions of space-time - serve as correlates of entanglement. An even stronger conjecture is that space-time somehow emerges from entanglement - I cannot get enthusiastic about this idea. Wormhole throats in GRT sense are not however stable but suffer a pinch splitting them.

   I have made an analogous proposal much earlier in TGD framework. Magnetic flux tubes would take the role or wormhole throats. Flux tubes would carry Kähler magnetic flux monopole Kähler magnetic flux making them stable.

   Remark: To avoid confusion let us make clear that wormhole throat in TGD framework means partonic 2-surface, which can be regarded either as the end of magnetic flux tube replacing wormhole throat understood in GRT sense.

3. Partonic 2-surface is the key notion in TGD, and it turns out that this could define the microscopic representation of 2-surface. The macroscopic continuous 2-surface would be

replaced with a union of partonic 2-surfaces and the generalization of Ruy-Taganaki formula [B47] for entanglement entropy would be formulated in terms of partonic 2-surfaces.

5.2.3 Hyperbolic tessellations are possible for both AdS and Minkowski space

What makes AdS_n so interesting from the point of view of holography and error correcting codes is that the hyperbolic tessellations for time= constant surfaces defining hyperbolic spaces can be used to define quantum holographic codes and states.

1. AdS has a slicing by hyperbolic spaces $t_2^2 - x_1^2 - .. = R^2 - t_1^2$ with slices labelled by $t_1^2 \leq R^2$. Hyperbolic spaces have infinite number of tessellations known also as tilings. The tile is defined as a double coset space $\Gamma \backslash SO(1,n)/SO(n)$, where Γ is an infinite discrete subgroup of $SO(1,n)$ with discontinuous action. Γ is analogous to a discrete subgroup of translations in Euclidian space.

   One can imagine of connecting each face of a given tile to the faces of neighboring tiles and interpret the connection as inputs and outputs and assign to each face an isometry at the level of state space. The tessellation would define a tensor network mapping the inputs assignable to the interior tiles to the boundary states of the network.

2. Remarkably, also Minkowski space appearing as factor of H allows slicing by 3-D hyperbolic spaces $H_3(a)$ defined as hyperboloids $t^2 - r^2 = a^2$ (mass shell in particle physics). This slicing is central in TGD based cosmology with a defining the size scale of the universe. I have already earlier proposed that these hyperbolic tessellations must have fundamental role in TGD.

   For instance, they could naturally define a discretization for $a = constant$ hyperboloids assignable to either tip of the causal diamond CD defined as intersection of future and past directed light-cones. The discretization would be naturally associated with the second boundary of CD and there are indications that astrophysical objects could be at cells of this kind of tessellation analogous to condensed matter lattices. Recession velocity equivalent to equivalently cosmic redshift and by Hubble's law equivalent to distance would be quantized. Evidence for this quantization exists [K57].

3. What is even more significant, a very large fraction of 3-manifolds are known to be hyperbolic manifolds in the sense that they allow hyperbolic metric [K57] [A2]. Thus one can say that they can be mapped to pieces of hyperbolic tessellation. The induce metric of the 3-surface is of course not hyperbolic in general. However, if 3-surface representable as graph from hyperbolic space $H_3(a)$ to CP_2 one can assign a hyperbolic metric to it by considering the metric for the projection to $H_3(a)$ as metric of the 3-surface.

   This seems to work for all 3-surfaces representable as graphs $H_3 \rightarrow CP_2$ but there could be problems due to the presence of boundary. If one allows the boundary of 3-surface to contain broken tiles, there seems to be a very large number of tessellations. The tessellation would be unique only if boundary tiles are required to be unbroken: this condition also implies that the tessellation need not exist.

   Accepting broken boundary tiles, one could say that the hyperbolic tessellation is induced to space-time surface and that space-time surface representable as graph $M^4 \rightarrow CP_2$ allows a slicing by hyperbolic tessellations. One can of course ask, whether the preferred extremal property allows only unbroken tiles. In this case the boundary of tessellation could correspond to light-like 3-surface at which the signature of the induced metric changes to Euclidian. This would fit nicely with the notion of SH.

   The 3-volume of hyperbolic manifold defined by the hyperbolic metric is a topological invariant. The Minkowskian 3-volume would be indeed same for all allowed deformations with fixed $H_3(a)$ projection. Hence all deformations preserving the graph property really correspond to the same hyperbolic 3-manifold whose topology would reduce to its boundary topology. Note that preferred extremal property implies effective 2-dimensionality and this might restrict dramatically the number of allowed 3-surfaces. For unbroken tiles the boundary of the 3-surface contributes to the topology. The absence of genuine boundaries apart from the causal boundaries implied by the change of the metric signature is strongly suggested by boundary conditions, and could be achieved by gluing of piece of tessellation and its deformed copy along boundaries and also this brings in non-trivial topology.

4. CP_2 as a compact coset space allows also tessellations by its discrete subgroups with finite number of tiles. These are analogous to Platonic solids. These tessellations might be interesting for 3-surfaces not allowing a representation as a graph of a map from $H_3(a)$ to CP_2. The Euclidian regions obtained as deformations of CP_2 type vacuum extremals are good candidates in this respect. Deformations of string like objects $M^2 \times S^2$, S^2 a geodesic sphere in CP_2 would allow naturally tessellations defined by the tessellations of H_1 and S^2. These objects would be rather simple from the point of view of complexity theory.

These observations suggest that the hyperbolic tessellations realizing the holography can be actualized in quantum TGD and that they could even define quantum holographic codes.

1. The lines connecting faces of the tiles serve as correlates for entanglement. If magnetic flux tubes mediating monopole flux take the role of lines, the only possibility is that tiles and magnetic flux tubes connecting the centers of tiles form a network. The braiding of the flux tubes is also possible and would make possible topological quantum computation.

2. Tiles could contain quantum states and dark matter realized as $h_{eff} = n \times h$ phases for fundamental quarks and leptons serving as building bricks of elementary particles defined a good candidate for these phases. What simplifies the situation is that there are good reasons for the localization of the modes of induced spinor fields at string world sheets and string world sheets can be associated with flux tubes.

3. tessellation should be seen as an idealized model only. Only the topology of the graph defined by the tessellation and perfect tensor character of entanglement seem to be important. Magnetic body could be thus dynamical. Flux tubes could get braided, they could reconnect, they could experience phase transitions changing the value of $h_{eff} = n \times h$ inducing reduction or increase of length also 2-knotting and braiding can be imagined in 4-D space-time and could bring in totally new kind of topological dynamics. These phase transitions are crucial in TGD inspired quantum biology.

   Flux tube networks could suffer phase transitions in which the character of the tile as hyperbolic manifold changes just like the condensed matter lattice can change its character and in living matter this kind of phase transitions might be important. This suggests that quantum complexity theory could be seen as counterpart of condensed matter physics at the level of magnetic body.

4. An interesting question is what happens to the tessellations as one approaches boundary of CD, which is part of light-cone boundary. The study of the metric demonstrates that the tessellation degenerates to the tip of CD at this limit and all information is lost. This suggests that the representative capacity of tessellation as a function of light-cone proper time a is measured by the 3-volume of the tessellation in hyperbolic metric. The condition that this volume is restricted inside CD restricts the range of radial coordinate r in $r_M = ar$ and the volume has maximum for some value $0 < a < T$, where T is the distance between the tips of CD. Light-boundary is metrically sphere: could Platonic solids define tessellations at this limit? Could one see this limit as the limit at which ordinary condensed matter physics emerges as the quantum information associated with hyperbolic tessellations disappears.

There are indications that in living matter and brain this kind of networks are realized and I have proposed that magnetic flux tubes define this kind of quantum computational networks in living matter. One could even say that space-time becomes sensorily conscious about itself by building this kind of networks analogous to coordinate grids.

These observations suggest that quantum holography and error correction codes might be realized at the level of magnetic bodies dynamically in TGD framework. They would not be essential for defining quantum TGD itself but living and intelligent systems could develop the tessellations to develop bodily sensory consciousness.

5.3 Entanglement and Physics of Quantum Complexity

Both Susskind (see http://tinyurl.com/y927h695) and Preskill [B25] emphasize entanglement as the key notion distinguishing between quantum and classical. Entanglement brings in complexity as an exponential decrease of the dimension of the state space and thus the number of states due to the possibility of entanglement. For instance, for classical 3-D spins the configurations space of N spins has dimension $3 \times N$. For quantal spins the complex dimension of state space is 2^N and exponentially larger. It is not perhaps exaggeration to say that the science of complex systems is science of entanglement. Quantum information science has started to seriously study various aspects of entanglement and build simple models.

The notion of entanglement is rather abstract. One can even entangle mutually non-interacting CFTs. This brings in mind Connes tensor product and corresponding entanglement relating to the inclusions of hyper-finite factors [K110]. This entanglement is not forced by interactions but by internal consistency and one might regard it as kinematical. Negentropic entanglement (NE) central for TGD and number theoretic vision is also this kind of kinematic entanglement having very little to do with ordinary dynamics. Surprisingly this is nothing but the entanglement associated with perfect tensors used in the construction of Preskill. Note however that NMP favors its generation.

5.3.1 Some general results

The understanding of the relationship between holography, geometry, and entanglement has evolved dramatically during the last decade and it was nice to become aware of the work done and find that it complements nicely my own work work done in the framework provided by TGD theory of consciousness as a generalization of quantum measurement theory to ZEO.

1. Ryu-Takayanagi formula [B47] for the entanglement entropy as area of minimal surface is key formula and generalizes the area-entropy relationship for blackholes having also interpretation as entanglement entropy. Another key idea is ER-EPR correspondence stating that entanglement as wormholes connecting the entangled systems as a correlate: magnetic flux tubes as correlate for entanglement is an old idea of TGD.

   I have also considered the possibility that the braiding of magnetic flux tubes could serve as correlate for entanglement. If flux tubes appear as pairs with opposite directions of magnetic flux then entanglement might have braiding as correlate. Braiding could be also - and probably is - something independent.

2. Tensor networks constructed using perfect tensors as a representation for strongly interacting systems is a key idea in the article of Preskill *et al* [B25]. The king idea is the notion of perfect tensor with $2n$ components defining entangled system which in TGD framework would be negentropically entangled in the special sense that all n-dimensional subsystems would be maximally entangled with their complement. These tensors can be also used to define quantum error correcting codes and hyperbolic tessellations allow to construct this kind of codes.

Multiscale Entanglement Renormalization Ansatz (MERA) [B30] (http://tinyurl.com/y9avp92y) allows to study numerically hierarchical systems with long range entanglement described by local scale-invariant Hamiltonians. MERA networks allow to estimate the ground state of the system.

1. Hierarchical arrays of tensors represent entanglement in different length scales. MERA can be see as a more general isometry from bulk to boundary than the tensor networks proposed by Preskill *et al.* MERA involves also unitary transformations induced de-entanglement in vertical direction. The isometries $V \rightarrow V \otimes V$ (see Fig. 1 of the article) can be made unitary by extension $|0\rangle \otimes V \rightarrow V \otimes V$. The added tensor factor $|0\rangle$ is analogous to ancilla state in quantum computation. The inverse of this map can be regarded as roughening operation and eventually all entanglement is eliminated as one goes upwards in MERA network.

2. AdS/CFT- MERA connection is proposed first by Swingle [B10] and tensor networks as its realization is mentioned also in the [B25]. AdS/CFT-MERA connection is discussed by Bao *et al* in [B21] (`http://tinyurl.com/y9a9lr29`). AdS/MERA correspondence is suggested to work only in scales longer than AdS scale, and argued to fail to be complete even above AdS scale. The argument starts from the observation that correspondence requires the assignment of length scales to the vertical and horizontal bonds of the MERA network (dimension is 2) and somekind of lattice in AdS is proposed. Authors are not yet aware about the possibility that hyperbolic tessellations might provide an elegant geometrization of MERA network utilizing the discrete symmetries of hyperbolic space and provide the needed scales: scaling invariance allows continuum of scale choices and AdS radius does not seem to matter.

   An open question (to me at least) is whether the unitary transformations are necessary for MERA as claimed by Bao *et al*, and whether the unitary steps are realizable in terms of tessellations: Preskill *et al* do not seem to have them in their construction.

Does MERA have a natural TGD counterpart?

1. The tessellations of H_3 induce tessellations of 3-surfaces in TGD framework and tessellation allows geometrization of the tensor networks as mere graphs.

2. tessellations are scaling invariant but one can ask whether there are natural length scales. Minkowski space does not have any intrinsic scale but the geometric twistor space $M^4 \times S^2$ of M^4 provides such a scale as S^2 radius given by Planck length if the view about twistorialization of TGD is correct [K41]. The physical picture suggests that already CP_2 scale (roughly 10^4 times Planck length) defines a lower bound for scales in which the analog of AdS/MERA correspondence can make sense.

3. p-Adic length scale hierarchy and hierarchy of Planck constants with scaled up versions of p-adic length scales are quantitative formulations for the hierarchies at space-time level and give rise to many-sheeted space-time. These hierarchies are accompanied by several other fractal hierarchies: for instance, in TGD inspired theory of consciousness conscious entities form a fractal hierarchy. A natural guess would be that p-adic length scale and their dark scaled up variants define a hierarchy of length scales below which holography cannot be realized exactly.

From TGD point of view hyperbolic tessellations and MERA have clearly been missing pieces of a puzzle.

5.3.2 Entanglement in TGD Universe

There are several notions related to entanglement and inspired by the construction of TGD inspired theory of consciousness.

1. Zero Energy Ontology (ZEO) is the basic new element forcing to reconstruct quantum measurement theory. This leads to a theory of consciousness and allows to identify what life and death of conscious entity be from the point of view of quantum physics [K9].

   For dark matter the outcome of state function reduction would not be random below the duration of the sequence of state function reductions to the same boundary of causal diamond (CD) defining the lifetime of conscious entity: life could be seen as generalized Zeno effect. The first reduction to the opposite boundary of CD forced by NMP to eventually occur would mean death of the conscious entity and subsequent re-incarnation at the opposite boundary of CD. This conclusion is not just an idea which happened to pass by: reaching it took almost a quarter of century!

2. The goal of complexity science is to understand and control complex quantum systems and the basic challenge is to overcome quantum decoherence. Here TGD view about dark matter suggests a solution. TGD predicts a hierarchy of quantum phases of ordinary matter labelled by the value of Planck constant $h_{eff} = n \times h$ for which quantum scales are scaled up so that macroscopic quantum coherence becomes possible [K36, K27, K28, K29, K30, K71]. The time scale for decoherence is expected also to scale up.

This hierarchy defines a hierarchy of conformal symmetry breakings possible also for ordinary conformal symmetry but for some reason remained un-recognized. This makes possible fractal symmetry breaking: the symmetry broken sub-algebra is isomorphic to the original one: symmetry breaking without symmetry breaking!

Second mystery of theoretical physics of last decades is the failure to realize that conformal invariance has a generalization to 4-D context due to the fact that light-cone boundary in 4-D Minkowski space is metrically 2-D. This symmetry is crucial for the construction of TGD as Kähler geometry and spinor structure of "World of Classical Worlds" (WCW). Unfortunately, my attempts to communicate this simple fact have been fruitless. Maybe the reasons are basically sociological: "people from Harward" simply refuse to take seriously what lower level organisms try to explain to them.

3. A further new element is Negentropy Maximization Principle (NMP) [K58], which serves as the basic variational principle of TGD inspired quantum measurement theory and also that of TGD inspired theory of consciousness. NMP states roughly that the negentropy gain in state function reduction is maximal. Mathematically NMP is very much like second law but applies to number-theoretic entanglement negentropy characterizing information content of the entire entangled system rather than ensemble entropy characterizing either member of of entangled pair so that no conflict with second law need to be implied. It indeed seems, that second law becomes scale dependent notion holding true only above the life-time of conscious entities involved.

4. NE is a further new element is brought by number theoretical vision. NE is possible if entanglement probabilities belong to an algebraic extension of rationals to which the parameters characterizing string world sheets and partonic 2-surfaces are assumed to belong.

   Remark: The restriction of parameters to be in algebraic extension means realization of finite measurement resolution at the level of WCW allowing to get rid of the problems related to breaking of basic symmetries in the discretization realized at space-time level.

   NE is defined as entangelement negentropy is defined as p-adic variant of entanglement entropy for a prime for which the entanglement entropy is minimal. This makes sense if the probabilities belong to algebraic extension.

   The p-adic entanglement entropy defined by the same formula as Shannon entropy but replacing ordinary logarithm of probability with the logarithm of the p-adic norm of probability can be negative so that it is better to talk about negentropy. The entanglement negentropy has interpretation as a measure of coscious information about the state of entangled system rather as entropy characterizing the lack of information about the state of either sub-system defining thermodynamical entropy.

   An important special case corresponds to NE for which density matrix is proportional to unit matrix: in this case the entanglement negentropy is maximal. The interpretation is that entanglement negentropy accompanies positively colored conscious experiences like experience of understanding and love. In the case of unit matrix it would correspond to meditative experience in which all distinctions are reported to disappear: this could relate to the fact that in this case any state basis is eigenstate of the density matrix.

5. Which states are characterized by NE and thus by algebraic entanglement probabilities? Could all states associated with the values $h_{eff}/h > 1$ be such states? This would make sense if the entanglement is in the discrete degrees of freedom implied by the n-dimensional covering of space-time surface.

6. There is a nice connection to quantum error correcting codes. Preskill *et al* [B25] introduce the notion of perfect tensor as a building brick of the tensor networks which they propose to give rise to a representation of holography using hyperbolic tessellations. Tensors define entangled states and perfect tensors have $2n$ k-valued indices such that any decomposition of the system to $2n$ states possesses maximal entanglement. This system has also the property that there is isometric embedding of any $n-k$ states to the state space spanned by $n+k$ states in the complement. This kind of system is ideal for error correcting quantum code

and would represent the stable subspace of states for which error correction is possible. The definition of the negentropically entangled system stable under is essentially the same!

7. NMP favors generation of NE. NE can be transferred between systems and can thus reduce for a given subsystem (just like thermodynamical entropy), it tends to increase for the entire Universe. NE is assigned with dark matter with non-standard value of Planck constant. This forces to reconsider the possibility that second law, which could be seen as a consequence of the randomness of the outcome of state function reduction, holds only for the visible matter with standard value of Planck constant and characterized by ordinary entanglement. A more precise formulation is that second law holds true in time scales longer than the time scale of the living systems involved: the death of conscious entity means ordinary state function at the opposite boundary of CD and therefore generates ensemble entropy. For NE the outcome is not random during the reduction sequence defining self as Zeno effect.

If this vision is on the correct track, the science of complexity would be also physics of dark matter, living matter, consciousness, and cognition.

5.4 Quantum Error Correcting Codes, Holography, and Tensor Networks

Quantum computer must be isolated from the environment that is keep the state of the computing system pure. In the world described by standard quantum theory alone it is however extremely difficult to prevent the generation of entanglement with environment in turn implying that the state obtained by tracing over the environmental degrees of freedom is non-pure: entanglement entropy is generated and decoherence occurs.

To avoid this error correction mechanisms have been developed.

1. The basic idea is that one has system, environment, and auxiliary system called ancilla. In the initial state the systems are unentangled but perturbations generate entanglement between system and environment (why not between ancilla and environment?). One can however perform a unitary transformation for the whole system transferring the entanglement from system-environment to environment-ancilla pair by performing a unitary transformation and by replacing ancilla essentially with a new one. Ancilla would function as trash bin.

2. The mirror image of this idea is actually familiar from TGD inspired theory of consciousness. NMP predicts that negentropy tends to increase in quantum jumps. The negentropy of individual systems can be however reduced. In particular, NE from the system can be stolen: this would define the quantum correlate for stealing as crime! Religious myths catch this idea. Eve could not avoid the temptation to eat the fruit from the tree of Good and Bad Knowledge! The error correcting code would perform just the opposite by cleaning away the parasitic entanglement.

3. In TGD based biological quantum computation this mechanism could be used to transfer conscious information from quantum computing system to other system. Cleaning would become picking of fruits! I have proposed that the fundamental function of metabolism is basically transfer of NE from nutrients to organism [K71].

In he ordinary computation error correcting codes replace bits with bit sequences for which additional bits serve as check bits allowing to detect whether one or more bits have changed. If the number of bits is below some number defining the code, the errors can be corrected. For an unpractical person like me, it was quite a surprise to learn that without this kind of error correction mechanisms IT technology would not be possible. Errors are not rare events but do occur all the time.

In quantum situation bits are replaced with qubits and error correcting code is defined by sub-space of the full code space. Quantum error correcting code maps logical qubits by Hilbert space isometry to an entangled state formed by a larger number of physical qubits. The image under the isometry defines code subpace.

A kind of quantum hologram in which the information is distributed between larger number of qubits is created. If the number of erratic qubits is below some threshold characterizing the code, the errors can be corrected by applying a unitary transformation determined by the erased bits. This is highly analogous to the properties of the ordinary hologram. These codes allow also also to protect some maximal number of logical bits and also to detect whether quantal eves-dropping has taken place.

This suggests a beautiful correspondence between the classical and quantal holographies in TGD framework.

1. Classical holography would be realized in terms of string world sheets and partonic 2-surfaces serving as holograms coding space-time surfaces as preferred extremals whereas quantum logical hologram would be realized in terms of fermions whose many-particle states at string world sheets and partonic 2-surfaces define quantum Boolean logic.

   WCW gamma matrices are constructed as combinations of the fermionic oscillator operators so that the classical and quantum holographies would correspond to WCW orbital degrees of freedom and spin degrees of freedom. Note also that the modes of WCW spinor fields are formally classical. In fact super-conformal symmetries relate the orbital and spin degrees of freedom of WCW so that also the two holographies might be closely related at deeper level.

2. This observation raises a question related to the interpretation and fundamental formulation of TGD [K111, K84]. The recent formulation assumes that Kähler-Dirac action is defined at entire space-time but that the solutions are localized to string world sheets: this guarantees the well-definedness of em charge if induced W gauge fields vanish at string world sheets. There are several other excellent reasons for assuming the localization.

   Could it be that also the induced spinor fields in the complement of partonic 2-surfaces and string world sheets are present just like interior degrees of freedom for space-time surfaces? Should one one follow supersymmetric instincts and holograpically continue also the spinor modes at string world sheets to the space-time interior just as one continues the string world sheets themselves? The holographic localization of the modes at string world sheets making possible conformal invariance at them would mean that all information about many-fermion states are carried by string world sheets.

5.4.1 Tensor networks

The concept of tensor network relies on the notion of isometry between Hilbert spaces, to the notion of perfect tensor defining a basic building brick for the networks defining isometry of logical qubits in the interior of 3-surface with the entangled states formed by physical qubits at the boundary. Hyperbolic tessellation is a further key concept. Two key results are that the isometry defining quantum holographic mapping of interior quantum states to boundary states can be realized in terms of tensor network assignable to the tessellation and entanglement entropy can be expressed as area for the surface separating subset of the boundary from its complement.

Hyperbolicity means negative curvature and for hyperbolic spaces means the existence of infinite number of tessellations with infinite number of cells allowing to build tensor networks. In 2-D case this is basically due to the negative sign of the angle deficit for a geodesic polygon: this favors regular tiles with large number of faces.

Group-theoretically this means that the discrete group defining the tessellation is infinite and there is infinite number of them. For constant curvature spaces with positive curvature this group is finite as also tessellation itself. Also the number of tessellations is finite - at least in the case of sphere (the 5 Platonic solids). By the way, Platonic solids might be interesting at the light-like boundary of CD resulting as a limit of hyperbolic space since it reduces to sphere metrically.

5.4.2 Isometries and perfect tensors

Unitary transformations of Hilbert space satisfying $UU^\dagger = Id$ are isometries preserving the inner product. The isometries from n-dimensional Hilbert space H_n to $n+k$-dimensional Hilbert space

H_{n+k} are possible and define embeddings.The inverse transformation is defined only in the subspace defined by the n-dimensional image and has k-dimensional kernel. If there are unitary transformations U and U' of the two Hilbert spaces satisfying $TU = U'T$ then $T^\dagger T \propto Id_n$ is satisfied.

For an isometry $T : H_1 \otimes H_2 \to H$ one can construct isometry $\tilde{T} : H_1 \to H \otimes H_2$ such that $\tilde{T}^\dagger \tilde{T} = dim(H_2)Id$ by simply moving a_2 from $|a_2 a_1\rangle$ to the right-hand side in the formula

$$T : |a_2 a_1\rangle \to \sum_b |b\rangle T_{ba_2 a_1} \quad ,$$

and by tracing to get

$$\tilde{T} : |a_1\rangle \to \sum_{ba_2} |ba_2\rangle T_{ba_2 a_1} \quad .$$

Tensor $T_{a_1 ,...,a_{2n}}$ defines entangled states by a contraction with quantum states in labelled by a_i defining the set of $2n$ indices with v values.

Perfect tensors have the defining property that for any decomposition of the index set to two parts A and its complement A^c, $|A| \leq |A^c|$ the map defined by the tensor from A to A^c is isometry. Furthermore, perfect tensor maps $m \leq n$ spins isometrically to $2n - m$ spins. This obviously defines code as mapping of $m \leq n$- spin states to $2n - m$-spin states. In particular, single spin is map to $2n-1$ spins isometrically. For any (n, n) decomposition perfect tensor defines absolutely maximally entangled states.

In the case considered spin is coded by a linear map to entangled $2n - 1$-spins state of physical spins and there is 1 protected logical spin. There is stability against the erasure of $n - 1$ physical spins. A party holding n spins has complete information about logical spin because the erasure of $n - 1$ spins is correctable. Party holding $n - 1$ spins has no information about the full state. One could say that local physics in interior is coded to non-local physics at boundary, which is just what happens also in the ordinary hologram.

This picture suggest a deep connection between quantum information theory, quantum measurement theory according to ZEO, and consciousness: NE is optimal from the point of view of error correction and therefore it is natural to assume NMP and adelic physics bringing in various p-adic physics as correlates for cognition.

5.4.3 Hyperbolic tessellations and holographic quantum states and codes

The key results of the work of Preskill *et al* [B25] is what they call toy model for the realization of holography at the level of quantum states using tensor networks associated with tessellations of 2-D hyperbolic space forming time= constant section of AdS_3. The results are believed to hold true also in higher dimensions.

There is infinite number of tessellations labelled by the discrete infinite groups of Lorentz group so that the number of tensor networks is infinite reflecting faithfully the fact that entanglement can be equated with quantum complexity. The tensor network mapping the localized interior states isometrically to entangled boundary states is highly non-unique. For instance, one can choose the part of boundary involved in many ways and there is infinite number of tessellations. This suggests also a physical definition of complexity. Complexity should be defined in terms of the minimal tensor network allowing to realize this isometry.

Preskill *et al* define holographic quantum states and quantum codes. For holographic quantum states each tile of the tessellation carries quantum numbers meaning that not all of the spins are contracted. One could interpret these states as an explicit realization of the isometric mapping of localized interior states to boundary states with their image defining the stable code space. These states should not be however possible if one interprets holography in strict sense. This forces to consider whether the notion of holography used is general enough - this will be considered later from TGD point of view. For quantum codes all interior spins are contracted and the state is pure boundary state. Two examples about tessellations involving hexagons and pentagons are discussed explicitly.

5.4.4 Entanglement structure of holographic states

In the case considered 3-surface is replaced with 2-surface and in this case Ryu-Takayanagi formula [B47] represents the entanglement entropy between sets A and A^c at the boundary of 2-surface as a length of a minimal geodesic of hyperbolic plane connecting the boundary points of A. In 3-D case one would have minimal 2-surface.

The unit of "area" for d-dimensional boundary used is $4G_{d+2}$, where G_D is Newtons's constant of D-dimensional gravitational theory. The formula follows by assuming Einstein's equations at low energies. The argument of Ryu and Takayanagi involves AdS/CFT duality and introduction of AdS blackhole. One has string theory description of gravitation in AdS, one takes long length scale limit of this theory by making AdS dynamical and then introduces blackholes: reader can decide whether to take these steps leading to the desired outcome seriously. The source of my own skepticism is that the long length scale limit of string theory at long length scales involves too much hand waving and has led to the landscape problem in super string models.

Remark: In TGD framework strong form of holography implies that for $d = 2$ AdS_4 is replaced by 4-D space-time surface. One avoids the S^6 factor of 10-D fictive embedding space altogether. 8-D embedding space is present but is completely non-dynamical. Possible blackhole like entities (the light-like orbits of partonic 2-surfaces) are associated in TGD based holography with space-time surface. Strings in AdS correspond to string worlds sheets in space-time. Clearly there are strong similarities but also crucial differences.

Preskill *et al* [B25] represent an argument for how Ryu-Takayanagi formula could be understood in terms of the isometry relating local states in interior and non-local states at boundary. The minimal geodesic defines what is called causal wedge. The local operators within the causal wedge can be mapped isometrically to those at the boundary. Or stated differently: logical qubits in interior can be isometrically mapped to physical many-qubit states at the boundary.

As far as I understand, only the graph property of the tessellation and perfect tensor serving as building brick of the isometry are essential so that deformations of the tessellations are possible. In the argument the minimal curve reduces to the number of tiles along the boundary of the causal wedge and the formula expresses only upper bound for the entanglement entropy. The formula is purely combinatorial and based on the number of spin states at each node and on the number of nodes along the minimal geodesic.

Also an algorithm for finding the mininal geodesic is considered. So called greedy geodesic constructible numerically by starting from a given perfect tensor at boundary and pushing it to interior by isometries defined by perfect tensor as far as this is possible is discussed. For tessellations the greedy geodesics associated with A and A^c coincide and define the minimal geodesic.

The notion of entanglement wedge is also considered. Within it the local operators in interior are mappable by isometry to the boundary operators. The authors consider multipartite entanglement and entanglement distillation but I am not specialist enough to attempt to relate this to TGD. Quantum error correction in holographic codes is also discussed in more detail. Some comments about information theoretic interpretation of blackholes are also represented and the problematic interpretation of holographic states is considered. Creation of blackhole would be analogous to an elimination of tiles in the interior and generating in this manner free induces and disjoint component to boundary.

5.5 TGD View about the Holographic States and Codes

5.6 TGD View about the Holographic States and Codes

The considerations of the article generalize to TGD rather easily. In TGD one has 3-D hyperbolic space H^3 as a sub-manifold of future light-cone (actually part of H^3 as sub-manifold of CD) so that possible problems due to the existence of closed time-like geodesics are avoided as also the objections due to the artificial nature of the conformal boundary. I have already described the geometric ideas.

5.6.1 Realization of the holographic states in terms of flux tube networks

For TGD point of view the most interesting question is whether also holographic states de

ning the code explicitly are possible as genuine physical states: it would be disappointing if the beautiful mathematics of hyperbolic 3-manifolds would not be realized physically. One could indeed consider of putting many-fermion states to the nodes of the tessellation in which the faces of tiles are connected by flux tubes and this would give kind of physical realization of holography.

Dark matter at magnetic flux tubes would represent higher level able to concretely represent physics at the lower level by realizing strong form of holography. Dark matter would have kind of sensory representations about the matter at lower levels of dark matter hierarchy. Biological systems would be this kind of systems since they build representations about environment - send themselves - some of them even about laws of physics (!)-, and there is evidence that in living matter kind of coordinate grids are realized [K75]: the proposed TGD interpretation is in terms of flux tube networks defining tensor networks mapping boundary states to interior states.

In TGD framework magnetic flux tubes carrying monopole Kahler magnetic flux are correlates for entanglement and could also define the edges of the tensor networks based on H^3 tessellations. Partonic 2-surfaces are however not homologically trivial and therefore not boundaries of anything: this is what makes them behave as Kähler monopoles and stabilizes both wormhole contacts and magnetic flux tubes. As a consequence, they appear as throats of wormhole contacts behaving like opposite sign magnetic charges. Even this is not enough: by the fact that magnetic flux lines must be closed, one must have pairs of wormhole contacts as a minimal structure and elementary particles are indeed modelled in this manner.

5.6.2 Generalization of the area formula for entanglement entropy

How the area law for entanglement entropy could generalize?

1. The replacement of entropy with its number theoretical variant, which becomes negative for NE, looks very natural in living matter. The growth of the network during time evolution discussed by Susskind in this lecture (see `http://tinyurl.com/y8zhhca5`) would not correspond to approach to chaos of thermal equilibrium but generation of NE and evolution at dark matter level! Second law would be manifested only at the level of visible matter since entanglement is always entropic for it.

   The phase transitions increasing Planck constant would generate NE and would scale up quantum length by $h_{eff}/h = n$ so that the networks would increase.

   Remark: It has become clear that instead of h one must have minimal value h_0 of h_{eff} which could be smaller than h [L18, L43].

   Susskind assigns the growth of the network to blackhole interiors containing kind of invisible growing part of the network. In TGD Universe the emergence of wormholes connected by flux tubes would correspond to the growth of the tensor network. The hyperbolic tessellations of H^3 defining hyperbolic structure at 3-surfaces representable as graphs $H^3 \to CP_2$ have scaling invariance as a symmetry.

   The growth of the tensor network would occur in quantum critical phase transitions increasing the value of Planck constant. It is known that there is no cosmic expansion in local scales: this seems to be conflict with expansion in cosmological scales. The explanation could be that the expansion in given scale occurs in jerkwise manner - perhaps via phase transitiond increasing h_{eff} permanently or possiblty temporarily followed by a phase transition increasing p-adic length scale and reducing h_{eff} back to the standard value so that the scale is not changed. I have actually proposed a model for Expanding Earth (motivation comes from the observations that continents fit nicely together if the radius of Earth is by a factor 1/2 smaller than it is now) in terms of a phase transition increasing Earth radius by a factor of two. Sudden increase of the information content of flux tube network would be in question - kind of eureka experience of Mother Gaia [K5]! The model explains also the mysterious emergence of highly evolved multicellular lifeforms in Cambrian explosion as life forms evolved in the underground oceans and burst to the surface of Earth in the phase transition creating also the oceans. Before Cambrian Explosion Earth would have been like Mars, which by the way has radius equal to 1/2 of the Earth's radius.

2. Tensor network discretizes the continuum view: in particular, the continuous minimal surface is replaced with a set consisting of tiles of the tessellation. Could this description emerge from TGD as a genuine microscopic description in which macroscopic area consists of sum over microscopic areas? Wormhole throats from which flux tubes defining the links of the tensor network emerge could indeed specify the boundary of 3-D surface at microscopic level. Consider a subset A consisting of wormholes throats and the complement A^c of this set.

3. Ryu-Takayanagi formula involves a 2-surface, whose boundary is same as the boundary between A and A^c. What is essential that this surface is separating. The entanglement entropy for $A - A^c$ pair is given by the area of the separating surface and the discretized version of this can be understood quite concretely by studying the tensor network. One should identify a separating 2-surface for this set and its complement in TGD framework.

   To separate the throat from environment one must cut both the throat and flux tubes emerging from it. One could do this for all flux tubes in the set leading to complement of the set - or to environment. The entanglement entropy (or maybe negentropy for dark particles) would be proportional to the sum of the cross sectional areas divided by some unit for area. This could be the area the area of CP_2 geodesic sphere. One can argue that the cutting of monopole flux tube is not possible physically since it would create two opposite monopole charges. One can certainly imagine open strings like objects with CP_2 projection, which is homologically trivial but preferred extremal property and boundary conditions probably do not allow this. A more plausible realization would be as a pair of parallel flux tubes with opposite directions of magnetic fluxes with are identical. Reconnection for this pair would cut the flux tube pair. This kind of U-shaped flux tube pairs are central in TGD model for living matter. They act as kind of tentacles sniffing the environment, and when two flux tubes pairs of this kind meet, they can reconnect if the fluxes are identical and magnetic field strengths are suciently near to each other - the fluxes are quantized by the monopole character of flux.

This microscopic picture seems to be considerably more flexible than the picture based on the consideration of the 3-surfaces with macroscopic boundary. For instance, the entanglement negentropy of blackhole horizon (or actually the surface defining the causal horizon of any astrophysical object as surface at which the signature of the induced metric changes) with environment could be expressed as sum of cross-sectional areas of flux tubes connecting the horizon to the environment. These flux tubes would mediate gravitational interaction. It would be essential that the networks emerge at the level of magnetic body and dark matter, not the ordinary matter.

What is somewhat troubling in the construction of Preskill *et al* involving interior spins is that these should not be present in macroscopic holography. Authors suggest the interpretation of the holes of the tensor network as blackholes giving rise to horizon as new part of boundary. In TGD framework spins as physical states would always have as building bricks wormhole throats so that one would have counterparts of boundary states also now so that this problem disappears.

TGD interpretation generalizes the interpretation of Preskill *et al* by allowing single wormhole throat as a minimal blackhole like entity. In fact, the counterparts of blackholes would in TGD framework correspond to macroscopic wormhole throats. Also anyonic systems in condensed matter physics could correspond to this kind of systems elementary particles would be glued to this large boundary surface by 3-D topological condensation somewhat like various objects like plants to the Earth's surface [K72].

5.6.3 Summary

AdS/CFT correspondence is not essential for the realization of tensor networks. TGD based holography works equally well and the hyperbolic space H^3 emerges naturally in this framework. TGD approach allows also to get rid of various problematic aspects of AdS/CFT correspondence (artificial character of AdS, time-like closed geodesics, AdS boundary is not real) and a microscopic generalization of the Ruy-Taganaki formula is possible. Only the combinatorial structure of the tessellation and the notion of perfect tensor matter from information theoretic point of view (Ryu-Takayanagi formula however requires Einstein's equations) and this allows considerable flexibility in the realization of tensor works. There are many ways to induce the tessellation from M^4 since boundary tiles need not be complete. Holography might allow much more general representations than ideal tessellations since all that matters is the topological structure of the graph involved and that the tensors used as building bricks are perfect. The maps expressing holography can be also composed from a large variety of different perfect tensors.

The tensor networks might be realized in TGD inspired quantum biology and rely on NE assignable to discrete dark matter degrees of freedom. I have already earlier considered the hypothesis that the coordinate grid like structure formed from flux tubes could define kind of template for the self-organization of biosystem in 4-D sense implied by ZEO. Quantum complexity could force a generalization of condensed matter physics to that associated with tessellations of H^3, the number of which is infinite!

There are many interesting questions not discussed. Quantum TGD can be regarded as "complex square root" of thermodynamics. What can one say about the first law of this quantum thermodynamics? What about the analog of the first law for the area law?

5.7 Tensor Networks and S-matrices

The concrete construction of scattering amplitudes has been the toughest challenge of TGD and the slow progress has occurred by identification of general principles with many side tracks. One of the key problems has been unitarity. The intuitive expectation is that unitarity should reduce to a local notion somewhat like classical field equations reduce the time evolution to a local variational principle. The presence of propagators have been however the obstacle for locally realized unitarity in which each vertex would correspond to unitary map in some sense.

TGD suggests two approaches to the construction of S-matrix.

1. The first approach is generalization of twistor program [K101]. What is new is that one does not sum over diagrams but there is a large number of equivalent diagrams giving the same outcome. The complexity of the scattering amplitude is characterized by the minimal diagram. Diagrams correspond to space-time surfaces so that several space-time surfaces give rise to the same scattering amplitude. This would correspond to the fact that the dynamics breaks classical determinism. Also quantum criticality is expected to be accompanied by quantum critical fluctuations breaking classical determinism. The strong form of holography would not be unique: there would be several space-time surfaces assignable as preferred extremals to given string world sheets and partonic 2-surfaces defining "space-time genes".

2. Second approach relies on the number theoretic vision and interprets scattering amplitudes as representations for computations with each 3-vertex identifiable as a basic algebraic operation [K101]. There is an infinite number of equivalent computations connecting the set of initial algebraic objects to the set of final algebraic objects. There is a huge symmetry involved: one can eliminate all loops moving the end of line so that it transforms to a vacuum tadpole and can be snipped away. A braided tree diagram is left with braiding meaning that the fermion lines inside the line defined by light-like orbit are braided. This kind of braiding can occur also for space-like fermion lines inside magnetic flux tubes and defining correlate for entanglement. Braiding is the TGD counterpart for the problematic non-planarity in twistor approach.

Third approach involving local unitary as an additional key element is suggested by tensor networks relying on the notion of perfect entanglement discussed by Preskill *et al* [B25].

1. Tensor networks provide an elegant representation of holography mapping interior states isometrically (in Hilbert space sense) to boundary states or vice versa for selected subsets of states defining the code subspace for holographic quantum error correcting code. Again the tensor net is highly non-unique but there is some minimal tensor net characterizing the complexity of the entangled boundary state.

2. Tensor networks have two key properties, which might be abstracted and applied to the construction of S-matrix in zero energy ontology (ZEO): perfect tensors define isometry for any subspace defined by the index subset of perfect tensor to its complement and the non-unique graph representing the network. As far as the construction of Hilbert space isometry

between local interior states and highly non-local entangled boundary states is considered, these properties are enough.

One cannot avoid the question whether these three constructions could be different aspects of one and same construction and that tensor net construction with perfect tensors representing vertices could provide and additional strong constraint to the long sought for explicit recipe for the construction of scattering amplitudes.

5.7.1 Objections

It is certainly clear from the beginning that the possibly existing description of S-matrix in terms of tensor networks cannot correspond to the perturbative QFT description in terms of Feynman diagrams.

1. Tensor network description relates interior and boundary degrees in holography by a isometry. Now however unitary matrix has quite different role. It could correspond to U-matrix relating zero energy states to each other or to the S-matrix relating to each other the states at boundary of CD and at the shifted boundary obtained by scaling. These scalings shifting the second boundary of CD and increasing the distance between the tips of CD define the analog of unitary time evolution in ZEO. The U-matrix for transitions associated with the state function reductions at fixed boundary of CD effectively reduces to S-matrix since the other boundary of CD is not affected.

   The only manner one could see this as holography type description would be in terms of ZEO in which zero energy states are at boundaries of CD and U-matrix is a representation for them in terms of holography involving the interior states representing scattering diagram in generalized sense.

2. The appearance of small gauge coupling constant tells that the entanglement between "states" in state spaces whose coordinates formally correspond to quantum fields is weak and just opposite to that defined by a perfect tensor. Quite generally, coupling constant might be the fatal aspect of the vertices preventing the formulation in terms of perfect entanglement.

   One should understand how coupling constant emerges from this kind of description - or disappears from standard QFT description. One can think of including the coupling constant to the definition of gauge potentails: in TGD framework this is indeed true for induced gauge fields. There is no sensical manner to bring in the classical coupling constants in the classical framework and the inverse of Kähler coupling strength appears only as multiplier of the Kähler action analogous to critical temperature.

   More concretely, there are WCW spin degrees of freedom (fermionic degrees of freedom) and WCW orbital degrees of freedom involving functional integral over WCW. Fermionic contribution would not involve coupling constants whereas the functional integral over WCW involving exponential of vacuum functional could give rise to the coupling constants assignable to the vertices in the minimal tree diagram.

3. The decomposition $S = 1 + iT$ of unitary S-matrix giving unitarity as the condition $-i(T - T^\dagger) + T^\dagger T = 0$ reflects the perturbative thinking. If one has only isometry instead of unitary transformation, this decomposition becomes problematic since T and $T^\dagger$ whose some appears in the formula act in different spaces. One should have the generalization of Id as a "trivial" isometry. Alternatively, one should be able to extend the state space H_{in} by adding a tensor factor mapped trivially in isometry.

4. There are 3- and 4-vertices rather than only -say, 3-vertices as in tensor networks. For non-Abelian Chern-Simons term for simple Lie group one would have besides kinetic term only 3-vertex $Tr(A \wedge A \wedge A)$ defining the analog of perfect tensor entanglement when interpreted as co-product involving 3-D permutation symbol and structure constants of Lie algebra. Note also that for twistor Grassmannian approach the fundamental vertices are 3-vertices. It must be however emphasized that QFT description emerges from TGD only at the limit when one identifies gauge potentials as sums of induced gauge potentials assignable to the space-time sheets, which are replaced with single piece of Minkowski space.

5. Tensor network description does not contain propagators since the contractions are between perfect tensors. It is to make sense propagators must be eliminated. The twistorial factorization of massless fermion propagator suggest that this might be possible by absorbing the twistors to the vertices.

These reasons make it clear that the proposed idea is just a speculative question. Perhaps the best strategy is to look this crazy idea from different view points: the overly optimistic view developing big picture and the approach trying to debunk the idea.

5.7.2 The overly optimistic vision

With these prerequisites on one can follow the optimistic strategy and ask how tensor networks could the allow to generalize the notion of unitary S-matrix in TGD framework.

1. Tensor networks suggests the replacement of unitary correspondence with the more general notion of Hilbert space isometry. This generalization is very natural in TGD since one must allow phase transitions increasing the state space and it is quite possible that S-matrix represents only isometry: this would mean that $S^\dagger S = Id_{in}$ holds true but $SS^\dagger = Id_{out}$ does not even make sense. This conforms with the idea that state function reduction sequences at fixed boundary of causal diamonds defining conscious entities give rise evolution implying that the size of the state space increases gradually as the system becomes more complex. Note that this gives rise to irreversibility understandandable in terms of NMP [K58]. It might be even impossible to formally restore unitary by introducing formal additional tensor factor to the space of incoming states if the isometric map of the incoming state space to outgoing state space is inclusion of hyperfinite factors.

2. If the huge generalization of the duality of old fashioned string models makes sense, the minimal diagram representing scattering is expected to be a tree diagram with braiding and should allow a representation as a tensor network. The generalization of the tensor network concept to include braiding is trivial in principle: assign to the legs connecting the nodes defined by perfect tensors unitary matrices representing the braiding - here topological QFT allows realization of the unitary matrix. Besides fermionic degrees of freedom having interpretation as spin degrees of freedom at the level of "World of Classical Worlds" (WCW) there are also WCW orbital degrees of freedom. These two degrees of freedom factorize in the generalized unitarity conditions and the description seems much simpler in WCW orbital degrees of freedom than in WCW spin degrees of freedom.

3. Concerning the concrete construction there are two levels involved, which are analogous to descriptions in terms of boundary and interior degrees of freedom in holography. The level of fundamental fermions assignable to string world sheets and their boundaries and the level of physical particles with particles assigned to sets of partonic 2-surface connected by magnetic flux tubes and associated fermionic strings. One could also see the ends of causal diamonds as analogous to boundary degrees of freedom and the space-time surface as interior degrees of freedom.

The description at the level of fundamental fermions corresponds to conformal field theory at string world sheets.

1. The construction of the analogs of boundary states reduces to the construction of N-point functions for fundamental fermions assignable to the boundaries of string world sheets. These boundaries reside at 3-surfaces at the space-like space-time ends at CDs and at light-like 3-surfaces at which the signature of the induced space-time metric changes.

2. In accordance with holography, the fermionic N-point functions with points at partonic 2-surfaces at the ends of CD are those assignable to a conformal field theory associated with the union of string world sheets involved. The perfect tensor is assignable to the fundamental 4-fermion scattering which defines the microscopy for the geometric 3-particle vertices having twistorial interpretation and also interpretation as algebraic operation.

What is important is that fundamental fermion modes at string world sheets are labelled by conformal weights and standard model quantum numbers. No four-momenta nor color quantum numbers are involved at this level. Instead of propagator one has just unitary matrix describing the braiding.

3. Note that four-momenta emerging in somewhat mysterious manner to stringy scattering amplitudes and mean the possibility to interpret the amplitudes at the particle level.

Twistorial and number theoretic constructions should correspond to particle level construction and also now tensor network description might work.

1. The 3-surfaces are labelled by four-momenta besides other standard model quantum numbers but the possibility of reducing diagram to that involving only 3-vertices means that momentum degrees of freedom effectively disappear. In ordinary twistor approach this would mean allowance of only forward scattering unless one allows massless but complex virtual momenta in twistor diagrams. Also vertices with larger number of legs are possible by organizing large blocks of vertices to single effective vertex and would allow descriptions analogous to effective QFTs.

2. It is highly non-trivial that the crucial factorization to perfect tensors at 3-vertices with unitary braiding matrices associated with legs connecting them occurs also now. It allows to split the inverses of fermion propagators into sum of products of two parts and absorb the halves to the perfect tensors at the ends of the line. The reason is that the inverse of massless fermion propagator (also when masslessness is understood in 8-D sense allowing M^4 mass to be non-vanishing) to be express as bilinear of the bi-spinors defining the twistor representing the four-momentum. It seems that this is absolutely crucial property and fails for massive (in 8-D sense) fermions.

5.7.3 Twistorial and number theoretic visions

Both twistorial and number theoretical ideas have given a strong boost to the development of ideas.

1. With experience coming from twistor Grassmannian approach, twistor approach is conjectured to allow an extension of super-symplectic and other superconformal symmetry algebras to Yangian algebras by adding a hierarchy of multilocal generators [K101]. The twistorial diagrams for $\mathcal{N} = 4$ SUSY can be reduced to a finite number and there is large number of equivalent diagrams. One expects that this is true also in TGD framework.

   Twistorial approach is extremely general and quite too demanding to my technical skills but its is a useful guideline. An important outcome of twistor approach is that the intermediate states are massless on-mass-shell states but with complex momenta. Does this generalize and could each vertex define unitary scattering event with complex four-momenta in possibly complexified Minkowski space? Or could even real momenta be possible for massive particles, which would be massless in 8-D sense thanks to the existence of octonionic tangent space structure of 8-D embedding space? And what is the role of the unique twistorial properties of M^4 and CP_2?

2. Number theoretical vision suggests that the scattering amplitudes correspond to sequences of algebraic operations taking inputs and producing outputs, which in turn serve as inputs for a neighboring node [K101]. The vertices form a diagram defining a network like structure defining kind of distributed computations leading from given inputs to given outputs. A computation leading from given inputs to given outputs is suggestive. There exists an infinite number of this kind of computations and there must be the minimal one which defines the complexity of the scattering. The maximally simplifying guess is that this diagram would correspond to a braided tree diagram. At space-time level these diagrams would correspond to different space-time surfaces defining same physics: this is because of holography meaning that only the ends of space-time surfaces at boundaries of CD matter.

   This vision generalizes of the old-fashioned stringy duality. It states that all diagrams can be reduced to minimal diagrams. This is achieved by by moving the ends of internal lines so that loops becomes vacuum tadpoles and can be snipped off. Tree diagrams must be however allowed to braid and outside the vertices the diagrams look like braids. Braids for which threads can split and glue together is the proper description for what the diagrams could be. Braiding would provide the counterpart for the non-planar twistor diagrams.

The fermion lines inside the light-like 3-surfaces can get braided. Smaller partonic 2-surfaces can topologically condense at given bigger partonic 2-surface (electronic parton surface can topologically condense to nano-scopic parton surface) and the orbits of the condensed partonic 2-surfaces at the light-like orbit of the parton surface can get braided. This gives rise to a hierarchy of braids with braids.

5.7.4 Generalization of the notion of unitarity

The understanding of unitarity has been the most difficult issue in my attempts to understand S-matrix in TGD framework. When something turns out to be very difficult to understand, it might make sense to ask whether the definition of this something involves un-necessary assumptions. Could unitarity be this kind of notion?

The notion of tensor network suggests that unitarity can generalized and that this generalization allows the realization of unitarity in extremely simple manner using perfect tensors as building bricks of diagrams.

1. Both twistorial and number theoretical approaches define M-matrix and associated S-matrix as a map between the state spaces H_{in} and H_{out} assignable to the opposite boundaries of CD - say positive and negative energy parts of zero energy state. In QFT one has $H_{in} = H_{out}$ and the map would be Hilbert space unitary transformation satisfying $SS^\dagger = S^\dagger S = Id$.

2. The basic structure of TGD (NMP favoring generation of negentropic entanglement, the hierarchy of Planck constants, length scale hierarchies, and hierarchy of space-time sheets) suggests that the time evolution leads to an increasingly complex systems with higher-dimensional Hilbert space so that $H_{in} = H_{out}$ need not hold true but is replaced with $H_{in} \subset H_{out}$. This view is very natural since one must allow quantum phase transitions increasing the value of h_{eff} and the value of p-adic prime defining p-adic length scale.

   S-matrix would thus define isometric map $H_{in} \subset H_{out}$. Isometry property requires $U^\dagger U = Id_{in}$. If the inclusion of H_{in} to H_{out} is a genuine subspace of H_{out}, the condition $UU^\dagger = Id_{out}$ does not make sense anymore. This means breaking of reversibility and is indeed implied by the quantum measurement theory based on ZEO.

3. It would be at least formally possible to fuse all state spaces to single very large state space by replacing isometry $H_{in} \subset H_{out}$ with unitary map $H_{out} \rightarrow H_{out}$ by adding a tensor factor in which the map acts as identity transformation. This is not practical since huge amounts of redundant information would be introduced. Also the information about hierarchical structure essential for the idea of evolution would be lost. This hierarchical of inclusions should also be crucial for understanding the construction of S-matrix or rather, the hierarchy of S-matrices of isometric inclusions including as a special case unitary S-matrices.

4. There is also a further intricacy, which might prevent the formal unitarization by the addition of an inert tensor factor. I have talked a lot about HFFs referring to hyper-finite factors of type II_1 (possibly also of type III_1) and their inclusions [K110]. The reason is that WCW spinors form a canonical representation for these von Neumann algebras.

   Could the isometries replacing unitary S-matrix correspond to inclusions of HFFs? In the recent interpretation the included factor (now H_{in}) corresponds to the degrees of freedom below measurement resolution. Certainly this does not make sense now. The interpretation in terms of finite measurement resolution need not however be the only possible interpretation and the interpretation in terms of measurement resolution might of course be wrong. Therefore one can ask whether the relation between H_{in} and H_{out} could be more complex than just $H_{out} = H_{in} \otimes H_1$ so that formal unitarization would fail.

5.7.5 Scattering diagrams as tensor networks constructed from perfect tensors

Preskill's tensor network construction [B25] realizes isometric maps as representations of holography and as models for quantum error correcting codes. These tensor networks have remarkable similarities with twistorial and number theoretical visions, which suggests that it could be used to construct scattering amplitudes. A further idea inspired by holography is that the description of scattering amplitudes in terms of fundamental fermions and physical particles are dual to each other.

1. In the construction of quantum error codes tensor network defines an isometric embedding of local states in the interior to strongly entangled non-local states at boundary. Their vertices correspond to tensors, which in the proposal of Preskill *et al* [B25] are perfect tensors such that one can take any m legs of the vertex and the tensor defines isometry from the state space of m legs to that of $n-m$ legs. When the number of indices is $2n$, the entanglement defined by perfect tensor between any n-dimensional subspace and its complement is maximal

   TGD framework maximal entanglement corresponds to negentropic entanglement with density matrix proportional to identity matrix. What is important that the isometry is constructed by composing local isometries associated with a network. Given isometry can be constructed in very many ways but there is some minimal realization.

2. The tensor networks considered in [B25] are very special since they are determined by tessellations of hyperbolic space H_2. This kind of tessellations of H_3 could be crucial for understanding the analog of condensed matter physics for dark matter and could appear in biology [L17]. What is crucial is that only the graph property and perfect tensor property matter as far as isometricity is considered so that it is possible to construct very general isometries by using tensor networks.

5.7.6 Eigenstates of Yangian co-algebra generators as a way to generate maximal entanglement?

Negentropically entangled objects are key entities in TGD inspired theory of consciousness and also of tensor networks, and the challenge is to understand how these could be constructed and what their properties could be. These states are diametrically opposite to unentangled eigenstates of single particle operators, usually elements of Cartan algebra of symmetry group. The entangled states should result as eigenstates of poly-local operators. Yangian algebras involve a hierarchy of poly-local operators, and twistorial considerations inspire the conjecture that Yangian counterparts of super-symplectic and other algebras made poly-local with respect to partonic 2-surfaces or end-points of boundaries of string world sheet at them are symmetries of quantum TGD [K41]. Could Yangians allow to understand maximal entanglement in terms of symmetries?

1. In this respect the construction of maximally entangled states using bi-local operator $Q^z = J_x \otimes J_y - J_x \otimes J_y$ is highly interesting since entangled states would result by state function. Single particle operator like J_z would generate un-entangled states. The states obtained as eigenstates of this operator have permutation symmetries. The operator can be expressed as $Q^z = f^z_{ij} J^i \otimes J^j$, where f^A_{BC} are structure constants of SU(2) and could be interpreted as co-product associated with the Lie algebra generator J^z. Thus it would seem that unentangled states correspond to eigenstates of J^z and the maximally entangled state to eigenstates of co-generator Q^z. Kind of duality would be in question.

2. Could one generalize this construction to n-fold tensor products? What about other representations of SU(2)? Could one generalize from SU(2) to arbitrary Lie algebra by replacing Cartan generators with suitably defined co-generators and spin 1/2 representation with fundamental representation? The optimistic guess would be that the resulting states are maximally entangled and excellent candidates for states for which negentropic entanglement is maximized by NMP [K58].

3. Co-product is needed and there exists a rich spectrum of algebras with co-product (quantum groups, bialgebras, Hopf algebras, Yangian algebras). In particular, Yangians of Lie

algebras are generated by ordinary Lie algebra generators and their co-generators subject to constraints. The outcome is an infinite-dimensional algebra analogous to one half of Kac-Moody algebra with the analog of conformal weight N counting the number of tensor factors. Witten gives a nice concrete explanation of Yangian [B16] for which co-generators of T^A are given as $Q^A = \sum_{i<j} f^A_{BC} T^B_i \otimes T^C_j$, where the summation is over discrete ordered points, which could now label partonic 2-surfaces or points of them or points of string like object (see `http://tinyurl.com/y727n8ua`). For a practically totally incomprehensible description of Yangian one can look at the Wikipedia article (see `http://tinyurl.com/y7heufjh`).

4. This would suggest that the eigenstates of Cartan algebra co-generators of Yangian could define an eigen basis of Yangian algebra dual to the basis defined by the totally unentangled eigenstates of generators and that the quantum measurement of poly-local observables defined by co-generators creates entangled and perhaps even maximally entangled states. A duality between totally unentangled and completely entangled situations is suggestive and analogous to that encountered in twistor Grassmann approach where conformal symmetry and its dual are involved. A beautiful connection between generalization of Lie algebras, quantum measurement theory and quantum information theory would emerge.

5.7.7 Two different tensor network descriptions

The obvious question is whether also unitary S-matrix of TGD could be constructed using tensor network built from perfect tensors. In ZEO the role of boundary would be taken by the ends of the space-time at upper and lower light-like boundaries of CD carrying the particles characterized by standard model quantum numbers. Strong form of holography would suggest that partonic surfaces and strings at the ends of CD provide information for the description of zero energy states and therefore of scattering amplitudes. The role of interior would be taken by the space-time surface - in particular the light-like orbits of partonic surfaces carrying the fermion lines identified as boundaries of string world sheets. Conformal field theory description would apply to fermions residing at string world sheets with boundaries at light-like orbits of partonic 2-surfaces.

In QFT Feynman diagrammatics one obtains a sum over diagrams with arbitrary numbers of loops. In both twistorial and number theoretic approach however only a finite number of diagrams with possibly complex on mass shell massless momenta are needed. If the vertices are however such that particles remain on-mass-shell but are allowed to have complex four-momenta then the integration over internal momenta (loops) is not present and tensor network description could make sense. This encourages the conjecture that tensor networks could be used to construct the scattering amplitudes in TGD framework.

What could perfect tensor property mean for the vertices identified as nodes of a tensor network? There are two levels to be considered: the geometric level identifying particles as 3-surfaces with net quantum numbers and the fermion level identifying particles as fundamental fermions at the boundaries of string world sheets.

1. At the geometric level vertices corresponds to light-like orbits of partonic 2-surfaces meeting at common end which is partonic 2-surface. This is 3-D generalization of Feynman diagram as a geometric entity. At the level of fermion lines associated with the light-like 3-surfaces one the basic interaction corresponds to the scattering of 2-fermions leading to re-sharing of fermion lines between outgoing light-like 3-surfaces, which include also representations for virtual particles. One has 4-fermion vertex but not in the sense that it appears in the interaction of weak interactions at low energies.

   Geometrically the basic vertex could be 3-vertex: $n > 3$-vertices are unstable against deformation to lower vertices. For 3-vertex perfect tensor property means that the tensor defining the vertex maps any 1-particle subspaces to 2-particle subspace isometrically. The geometric vertices define a network consisting of 3-D "lines" and 2-D vertices but one cannot tell what is within the 3-D lines and what happens in the 2-D nodes. The lines would consist of braided fundamental fermion lines and in nodes the basic process would be 2+2 scattering for fermions. In the case of 3-vertex momentum conservation would effectively eliminate the four-momentum and the state spaces associated with vertex would be effectively discrete. This is p-adically of utmost importance.

2. At the level of fundamental fermion lines in the interior of particle lines one would have 4-vertices and if a perfect tensor describes it, it gives rise to a unitary map of any 2-fermion subspace to its complement plus isometric maps of 1-fermion subspaces to 3-fermion subspaces. In this case momenta cannot act as labels of fermion lines for rather obvious reasons: the solution of the problem is that conformal weights label fundamental fermion lines

   The conservation of discrete quark and lepton numbers allows only vertices of type $qL \rightarrow qL$ and its variants obtained by crossing. In this case the isometries might allow realization. The isometries must be defined to take into account quark and lepton number conservation by crossing replacing fermion with antifermion. By allowing the states of Hilbert space in node to be both quarks and leptons, difficulties can be avoided.

Tensor network description in terms of fundamental fermions and CFT

Consider first fundamental fermions. What are the labels characterizing the states of fundamental fermions fermions propagating along the lines? There are two options: the labels are either conformal weights or four-momenta.

1. Since fermions corresponds to strings defining the boundaries of string world sheets and since strong form of holography implies effective 2-dimensionality also in fermion sector, the natural guess is that the conformal weights plus some discrete quantum numbers - standard model quantum numbers at least - are in question. The situation would be well-defined also p-adically for this option. In this case one can hope that conformal field theory at partonic 2-surface could define the fermionic 4-vertex more or less completely. There would be no need to assign propagators between different four-fermion vertices. The scattering diagram would define a composite formed from light-like 3-surfaces and one would have single isometry build from 4-fermion perfect tensors. There would be no integrations over internal momenta.

2. Second option is that fundamental fermions are labelled by four-momenta. The outgoing four-momenta in 4-vertices would not be completely fixed by the values of the incoming momenta and this extends the state space. Concerning p-adicization this integral is not desirable and this forces to consider seriously discrete labelling. The unitarity condition for 2+2 scattering would involve integral over 2-sphere. Four-fermion scattering must be unitary process in QFT so that this condition might be possible to satisfy. The problem would be how to fix this fundamental scattering matrix uniquely. This option does not look attractive number theoretically.

The most plausible option is that holography means that conformal field theory describes the scattering of fundamental fermions and QFT type description analogous to twistorial approach describes the scattering of physical fermions. If only 3-vertices are allowed, and if masslessness corresponds to masslessness in 8-D sense, one obtains non-trivial scattering vertices (for ordinary twistor approach all massless momenta would be collinear if real).

Tensor network description for physical particles

Could the twistorial description expected to correspond to the description in terms of particles allow tensor network description?

1. Certainly one must assign four-momenta to incoming *physical* particles - also fermions - but they correspond to pairs of wormhole contacts rather than fundamental fermions at the boundaries of string world sheets. It would be natural to assign four-momenta also to the virtual *physical* fermions appearing in the diagram and the geometric view about scattering would allow only 3-vertices so that momentum conservation would eliminate momentum degrees of freedom effectively. This would be a p-adically good news.

2. At the level of fundamental fermions entanglement is described as a tensor contraction of the CFT vertices. This locality is natural since the vertices are at null distance from each other. At QFT limit the entanglement between the ends of the line is characterized the propagator.

   One must get rid of propagators in order to have tensor network description. The inclusion of propagators to the fundamental tensor diagrams would break the symmetry between the legs of vertex since the propagator cannot be included to its both ends. Situation changes if one can represent the propagator as a bilinear of something more primitive and include the halves to the opposite ends of the line. Twistor representation of four-momentum indeed defines this kind of representation as a bilinear $p^{a\tilde{b}} = \lambda\tilde{\mu}^{\tilde{b}}$ of twistors λ and $\tilde{\mu}$. There is problem due to the diverging $1/p^2$ factor but residue integral eliminates this factor and one can write directly the fermionic propagator factors as $p^{a\tilde{b}}$.

3. In QFT description the perturbative expansion is in powers of coupling constant. If the reduction to braided tree diagrams analogous to twistor diagrams occurs, power g^{N-2} of coupling constant is expected to factorize as a multiplier of a tree diagram with N external legs. One should understand this aspect in the tensor net-work picture.

   For $\mathcal{N}=4$ SUSY there is coupling constant renormalization. Similar prediction is expected from TGD. Coupling constant evolution is expected to be discrete and induced by the discrete evolution of Kähler coupling strength defined by the spectrum of its critical values. The conjecture is that critical values are naturally labelled by p-adic primes $p \simeq 2^k$, k prime, labelling p-adic length scales. Therefore one might hope that problems could be avoided.

These observations encourage the expectation that twistorial approach involving only 3-vertices allows to realize tensor network idea also at the level of physical particles. It might be essential that twistors can be generalized to 8-D twistors. Octonionic representation of gamma matrices might make this possible. Also the fact twistorial uniqueness of M^4 and CP_2 might be crucial.

Gauge theory follows as QFT limit of TGD so that one cannot in principle require that gauge theory vertices satisfy the isometricity conditions. Nothing however prevents from checking whether gauge theory limit might inherit this property.

1. For instance, could 3-vertices of Yang-Mills theory define isometric embedding of 1-particle states to 2 particle states? For a given gauge boson there should exist always a pair of gauge bosons, which can fuse to it. Consider a basis for Lie-algebra generators of the gauge group. If the generator T is such that there exists no pair $[A, B]$ with the property $[A, B] = T$, Jacobi identity implies that T must commute with all generators and one has direct sum of Lie algebras generated by T and remaining generators.

2. In the case of weak algebra $SU(2) \times U(1)$ the weak mixing of Y and I_3 might allow the isometric embeddings of type $1 \rightarrow 2$. Does this mean that Weinberg angle must be non-vanishing in order to have consistent theory? A realistic manner to get rid of the problem is to allow at QFT limit the lines to be also fermions so that also U(1) gauge boson can be constructed as fermion pair.

How the two tensor network descriptions would be related?

There are two descriptions for the zero energy states providing representation of scattering amplitudes: the CFT description in terms of fundamental fermions at the boundaries of string world sheets, and the description in terms of physical particles to which one can assign light-like 3-surfaces as virtual lines and total quantum numbers.

1. CFT description in terms of fundamental fermions in some aspects very simple because of its 2-dimensionality and conformal invariance. The description is in terms of physical particles having light-like 3-surfaces carrying some total quantum numbers as correlates and is simpler in different sense. These descriptions should be related by an Hilbert space isometry.

2. The perfect tensor property for 4-fermion vertices makes fundamental fermion states analogous to physical states realizing logical qubits as highly entangled structures. Geometric description in terms of 3-surfaces is in turn analogous to the description in terms of logical qubits.

3. Holography-like correspondence between these descriptions of zero energy states (scattering diagrams) should exist. Physical particles should correspond to the level, at which resolution is smaller and which should be isometrically mapped to the strongly entangled level defined by

fundamental fermions and analogous to boundary degrees of freedom (fundamental fermions *are* at the boundaries of string world sheets!).

The map relating the two descriptions seems to exist. One can assign four-momenta to the legs of conformal four-point function as parameters so that one obtains a mapping from the states labelled by conformal weights to the states labelled by four-momenta! The appearance of 4-momenta from conformal theory is somewhat mysterious looking phenomenon but this duality makes it rather natural.

5.7.8 Taking into account braiding and WCW degrees of freedom

One must also take intro account braiding and orbital degrees of freedom of WCW. The generalization of tensor network to braided tensor network is trivial. Thanks to the properties of tensor network orbital and spinor degrees of freedom factorize so that also the treatment of WCW degrees of freedom seems to be possible.

What about braiding?

The scattering diagrams would be tree diagrams with braiding of fermionic lines along light-like 3-surfaces - dance of fundamental quarks and leptons at parquette defined by the partonic 2-surface one might say. Also space-like braiding at magnetic flux tubes at the ends of CD is possible and its time evolution between the ends of space-time surfaces defines 2-braiding which is generalization of the ordinary braiding but will not be discussed here. This gives rise to a hierarchy of braidings. One can talk about flux tubes within flux tubes and about light-like 3-surface within light-like 3-surfaces. The smaller light-like 3-surface would be glued by a wormhole contact to the larger one and contact could have Euclidian signature of induced metric.

How can one treat the braiding in the tensor network picture? The answer is simple. Braiding corresponds to an element of braid group and one can represent it by a unitary matrix as one does in topological QFT as one constructs knot invariants. In particular, the trace of this unitary matrix defines a knot invariant. The generalization of the tensor network is simple. One attaches to the links connecting two nodes unitary transformation defining a representation of the braid involved. Local variant of unitarity would mean isometricity at nodes and unitarity at links.

What about WCW degrees of freedom?

The above considerations are about fermions that its WCW spinor degrees of freedom and the space-time surface itself has been regarded as a fixed background. How can one take into account WCW degrees of freedom?

The scattering amplitude involves a functional integral over the 3-surfaces at the ends of CD. The functional integration over WCW degrees of freedom gives an expression depending on Kähler coupling strength α_K and determines the dependence on various gauge coupling strengths expressible in terms of α_K. This makes it possible to have the tensor network description in fermionic degrees of freedom without losing completely the dependence of the scattering amplitudes on gauge couplings. By strong form of holography the functional integral should reduce to that over partonic 2-surfaces and strings connecting them. Number theoretic discretization with a cutoff determined by measurement resolution forces the parameters characterizing the 2-surfaces to belong to an algebraic extension of rationals and is expected to reduce functional integral to a sum over discretized WCW so that it makes sense also in p-adic sectors [K84, K109].

A brief summary of quantum measurement theory in ZEO is necessary. The repeated state function reduction shifts active boundary A of CD and affects the states at it. The passive boundary of CD- call it P - and the states at it - remain unaffected. The repeated state function reductions leaving P unaffected and giving usually rise to Zeno effect, correspond now to the TGD counterpart of unitary time evolution by shifts between subsequent state function reductions. Call A and its shifted version A_{in} and A_{out} and the corresponding state spaces H_{in} and H_{out}. The unitary (or more generally isometric) S matrix represents this shift. This is the TGD counterpart of a unitary evolution of QFTs. S forms a building brick of a more general unitary matrix U acting in the space of zero energy states but U is not considered now.

Consider now the isometricity conditions.

1. Unitarity conditions generalized to isometricity conditions apply to S. Isometricity conditions $S^\dagger S = Id_{in}$ can be applied at A_{in}. The states appearing in the isometry conditions as initial and final states correspond to A_{in} and A_{out}. There is a trace over WCW spin indices (labels for many-fermion states) of H_{out} in the conditions $S^\dagger S = Id_{in}$. Isometricity conditions involve also an integral over WCW orbital degrees of freedom at both ends: these degrees of freedom are strongly correlated and for a strict classical determinism the correlation between the ends is complete. If the tensor network idea works, the summation over spinor degrees of freedom at A_{out} gives just a unit matrix in the spinor indices at A_{in} and leaves only the WCW orbital degrees of freedom in consideration. This factorization of spinor and orbital WCW degrees of freedom simplifies the situation dramatically.

2. One can express isometricity conditions for modes with $\Psi_{in,M}$ and $\Psi_{out,N}$ at A_{in} and A_{out}: this requires functional integration over 3-surfaces WCW at A_{in} and A_{out}. The conditions are formulated in terms of the labels - call them M_{in}, N_{in} - of WCW spinor modes at A_{in} including standard model quantum numbers and labels characterizing the states of supersymplectic and super-conformal representations. The trace is over the corresponding indices R_{out} at A_{out}. The WCW functional integrals in the generalized unitarity conditions are therefore over A_{in} and A_{out} and should give Kronecker delta $\sum_{R_{out}} S^\dagger_{M_{in}R_{out}} S_{R_{out}N_{in}} = \delta_{M_{in},N_{in}}$.

3. The simplest view would be that Kähler action with boundary conditions implies completely deterministic dynamics. The conditions expressing strong form of holography state that sub-algebras of super-symplectic algebra and related conformal algebras isomorphic to the entire algebra give rise to vanishing Noether charges. Suppose that these conditions posed at the ends of CD are so strong that they fix the time evolution of the space-time surface as preferred extremal completely when posed at either boundary. In this case the isometricity conditions would be so strong that the double functional integration appearing in the matrix product reduces to that at A_{in} and the isometricity conditions would state just the orthonormality of the basis of WCW spinor modes at A_{in}.

4. Quantum criticality and in particular, the hierarchy of Planck constants providing a geometric description for non-deterministic long range fluctuations, does not support this view. Also the fact that string world sheets connect the boundaries of CD suggests that determinism must be broken. The inner product defining the completeness of the WCW state basis in orbital degrees of freedom can be however generalized to a bi-local inner product involving functional integration over 3-surfaces at both A_{in} and A_{out}. There is however a very strong correlation so that integration volume at A_{out} is expected to be small. This also suggests that one can have only isometricity conditions.

5.7.9 How do the gauge couplings appear in the vertices?

Reader is probably still confused and wondering how the gauge couplings appear in the vertices from the functional integral over WCW degrees of freedom. In twistorial approach, the vanishing of loops in $\mathcal{N}=4$ SYM theory gives just g^N, N the number of 3-vertices. Each vertex should give gauge coupling. Or equivalently, each propagator line connecting vertices should give α_K. The functional integral should give this factor for each propagator line. Generalization of conformal invariance is expected to give this picture.

To proceed some basic facts about N-point functions of CFTs are needed.

1. In conformal field theory the functional form of two-point function is completely fixed by conformal symmetry:

$$\begin{aligned} G^{(2)}(z_i,\overline{z}_i) &= \frac{C_{12}}{z_{12}^{2h}\overline{z}_{12}^{2\overline{h}}} \ , \\ z_{ij} &= z_i - z_j \ , \ \overline{z}_{ij} = \overline{z}_i - \overline{z}_j \ , \\ h_1 = h_2 = h &= h_a + ih_b \ , \ \overline{h} = \overline{h}_a + i\overline{h}_b \ . \end{aligned} \quad (5.7.1)$$

$h_1 = h_2 \equiv h$ and its conjugate $\overline{h}$ are conformal weights of conformal field and its conjugate. Note that the conformal weights of conformal fields Φ_1 and Φ_2 must be same. In TGD context C_{12} is expected to be proportional to α_K and this would give to each vertex g_K when couplings are absorbed into vertices.

2. The 3-point function for 3 conformal fields Φ_i, $i = 1, 2, 3$ is dictated by conformal symmetries apart from constant C_{123}:

$$G^{(3)}(z_i, \overline{z}_i) = C_{123} \times \frac{1}{z_{12}^{h_1+h_2-h_3} z_{23}^{h_2+h_3-h_1} z_{31}^{h_3+h_1-h_2}} \times \frac{1}{\overline{z}_{12}^{\overline{h}_1+\overline{h}_2-\overline{h}_3} \overline{z}_{23}^{\overline{h}_2+\overline{h}_3-\overline{h}_1} \overline{z}_{31}^{\overline{h}_3+\overline{h}_1-\overline{h}_2}} . \tag{5.7.2}$$

Here C_{123} should bef fixed by super-symplectic and related symmetries and determined the numerical coefficients various couplings when expressed in terms of g_K.

3. 4-point functions have analogous form

$$\begin{aligned} G^{(4)}(z_i, \overline{z}_i) &= f_{1234}(x, \overline{x}) \prod_{i<j} z_{ij}^{-(h_i+h_j)+h/3} \prod_{i<j} \overline{z}_{ij}^{-(\overline{h}_i+\overline{h}_j)+\overline{h}/3} , \\ h &= \sum_i h_i , \end{aligned} \tag{5.7.3}$$

but are proportional to an arbitrary function f_{1234} of conformal invariant $x = z_{12}z_{34}/z_{13}z_{24}$ and its conjugate.

If only 3-vertices appear/are needed for physical particles - as both twistorial and number theoretic approaches strongly suggest - the conformal propagators and vertices are fixed apart from constants C_{ijk}, which in turn should be fixed by the huge generalization of conformal symmetries. α_K emerges in the expected manner.

This picture seems to follow from first principles.

1. One can fix the partonic 2-surfaces at the boundaries of CD but there is a functional integral over partonic 2-surfaces defining the vertices: their deformations induce deformations of the legs. One can expand the exponent of Kähler action and in the lowest order the perturbation term is trilinear and non-local in the perturbations. This gives rise to 3-point function of CFT nonlocal in z_i. The functional integral over perturbations gives the propagators in legs proportional to α_K in terms of two point function of CFT. Note that the external propagator legs can be eliminated in S-matrix.

2. The cancellation of higher order perturbative corrections in WCW functional integral is required by the quantum criticality and means trivial coupling constant evolution for α_K and other coupling constants. Coupling constant evolution is discretized with values of α_K analogous to critical temperatures and should correspond to p-adic coupling constant evolution [K35].

3. This picture leaves a lot of details open. An integration over the values of z_i is needed and means a kind of Fourier analysis leading from complex domain. The analog of Fourier analysis would be for deformations of partonic 2-surface labelled by some natural labels. Conformal weights could be natural labels of this kind.

It is easy to get confused since there are several diagrammatics involved: the topological diagrammatics of 3-surfacse assignable to the physical particles with partonic 2-surfaces as vertices, the diagrammatics associated with the perturbative functional integral for the Kähler action, and the fermionic diagrammatics suggested to reduce to tensor network. The conjectures are as follows.

1. The "primary" vertices $G^{(n)}$, $n > 3$ assignable to single partonic 2-surface and coming from a functional integral for Kähler action vanishes. This corresponds to quantum criticality and trivial RG evolution.

2. $G^{(n)}$, $n > 3$ in the sense of topological diagrammatics without loops and involving n partonic 2-surfaces do not vanish. One can construct the analog of $G^{(4)}$ from two $G^{(3)}$:s at different partonic 2-surfaces and propagator defined by 2-point function connecting them as string diagram.

   Also topological variant of $G^{(4)}$ assignable to single partonic 2-surface can be constructed by allowing the 3-D propagator "line" to return back to the partonic 2-surface. This would correspond to an analog of loop. Similar construction applies to "primary" $G^{(n)}$,$n > 4$. In number theoretic vision these loops are eliminated as redundant representations so that one has only braided tree diagrams. Also twistor Grassmann approach supports this view.

To sum up, the tensor network description would apply to fermionic degrees of freedom. In bosonic degrees of freedom functional integral would give CFT picture with 3-vertex as the only "primary" vertex and from this twistorial and number theoretic visions follow via the super-symplectic symmetries of the vertex coefficients C_{ijk} extended to Yangian symmetries.

Chapter 6

Quantum Gravitation and Topological Quantum Computation

6.1 Introduction

In this article the connection of quantum gravitation, as it is understood in the TGD framework, with topological quantum computation (TQC) is considered. I sketched the first TGD based vision about DNA as a TQCer for about 13 years ago. In particular, a model of the system consisting of DNA and nuclear/cell membrane system acting as a TQCer was discussed [K4, K3, K105].

TGD has evolved a lot after this and there are several motivations for seeing what comes out from combining the recent view about quantum TGD and TGD inspired quantum biology with this model.

1. There is a rather detailed view about the role of dark matter as phases of ordinary matter with the effective Planck constant $h_{eff} = nh_0$. Large values of h_{eff} allow to overcome the problems due to the loss of quantum coherence.

   This leads to the notion of the dark DNA (DDNA), whose codons are realized as dark proton triplets and proposed to accompany the ordinary DNA [L15, L96]. Also dark photon triplets are predicted [L7] [L58, L69] and one ends up to a model of communications and control based on dark cyclotron resonance in which codons serve as addresses and modulation of the signal frequency scale codes the signal to a sequence of pulses. Nerve pulses could be one application.

2. Quite recently, also the understanding of the possible role of quantum gravitation in biochemistry, metabolism, bio-catalysis, and in the function of DNA [L85] has considerably increased. The gravitational variants of hydrogen bonds and valence bonds between metal ions having very large value of $h_{eff} = h_{gr}$, where $h_{gr} = GMm/v_0$ is the gravitational Planck constant [L40] [K88, K68, K71] originally introduced by Nottale [E1], are in a key role in the model and explain metabolic energy quantum as gravitational energy liberated when dark protons "drops" from a very long gravitational flux tube in the transition $h_{gr} \to h$. Also electronic metabolic energy quantum is predicted and there is empirical support for this.

3. A further motivation comes from the number theoretic vision of quantum TGD. Galois groups as symmetry groups represent new physics [L67, L64, L66] and the natural questions are whether Galois groups could give rise to number theoretic variants of anyons and what could the TGD counterparts of the condensed matter (effective) Majorana electrons proposed by Kitaev [D19] as anyon like states?

   The answer is that quantum superpositions of symmetric hydrogen bonded structures of form X..H-H+X-H...X are excellent candidates for the seats of dark ($h_{eff} > nh_0 > h$) bi-localized electrons defining TGD analogs of condensed matter Majorana electrons.

The Galois groups permute the roots of a polynomial, which determines a space-time region by $M^8 - H$ duality. The roots correspond to mass squared values, in general algebraic numbers, and thus to mass hyperboloids in $M^4_c \subset M^8_c$. The H images correspond to 3-hyperboloids with a constant value of light-cone proper time. Therefore the Galois group permutes points with time-like separation.

This looks very strange at first but actually confirms with the fact that time-like braidings defining TQC correspond in TGD time-like braidings (involving also reconnections) of string like objects defining string world sheets, which are not now time evolutions of space-like entities as physical state but correspond to time-like entities defining boundary data necessary for fixing holography completely. Their presence is forced by the small failure of the determinism of the action principle involved and is completely analogous to the non-determinism for soap films with frames serving as seats for the failure of determinism.

4. Braidings appear therefore at the level of fundamental TGD and correspond to string world sheets. They are possible only in 4-D space-time but not in string models.

   Also TQC-like processes appear automatically at the level of fundamental physics. In particular, the number theoretical state function reduction cascade for the Galois group [L60] following the time evolution induced by braiding can be regarded as a generalization of a decomposition of integers to primes: now primes are replaced by simple groups defining primes for finite groups. Nature is doing number theory!

5. Also zero energy ontology (ZEO) [L52, L73] brings in new elements. The change of the arrow of time in "big" state function reductions (BSFRs) implies that dissipation with a reversed arrow of time provides an automatic error correction procedure. Also TQC in which the arrow of time varies for sub-modules, can be considered.

6.1.1 Two visions about physics in TGD framework

TGD leads to two visions about physics discussed in [L59, L77]. In the first vision [K50, K25, K84] physics is seen as geometry of space-time identified as 4-surface in $H = M^4 \times CP_2$, and at a more abstract level, geometry of the "world of classical worlds" (WCW) consisting of space of preferred extremals (PEs) of the basic action principle defining analogs of Bohr orbits as minimal surfaces with singularities.

In the second vision [K96] physics is reduced to number theoretic concepts and 4-surfaces in M^8 analogous to momentum space define the basic objects. $M^8 - H$ duality [L53, L54], analogous to momentum-position duality, relates the two visions. The 4-surfaces in M^8_c (complexified M^8), which has interpretation as complexified octonions, are required to be associative in the sense that their normal space is quaternionic.

For given space-time region, they are determined by the roots of polynomial P of real argument continued to polynomials in M^8_c. The roots define a collection of mass shells of $M^4_c \subset M^8_c$ and by holography they define a 4-D surface of H.

The action principle at the level of H is determined by the twistor lift of TGD and is the sum of 4-D Kähler action and volume term (cosmological constant). It is not fully deterministic and space-time surfaces in H as PEs analogous to Bohr orbits can be regarded as analogs of soap films with frames, which correspond to singularities at which determinism fails.

The frames provide additional holographic data besides the hyperbolic 3-surfaces corresponding to light-bone proper times $a = a_n$ which are determined by the roots of P. Frames include light-like orbits of partonic 2-surfaces and string world sheets connecting them. What is new, and consistent with zero energy ontology (ZEO) [K113], is that space-like data are not enough for holography, also time-like data is required and the string world sheets turn out to be absolutely essential for braiding and TQC.

Physics as geometry

The basic elements of physics as geometry are following.

1. Space-time is identified as minimal 4-surface [L79] in $H = M^4 \times CP_2$. Holography follows from general coordinate invariance and implies what might be called Bohr orbitology. It turns out that holography is not quite strict.

2. Twistor lift of TGD [L37] [L80, L81] replaces space-time surface with what can be regarded as a counterpart of its twistor space having X^4 as a base space and sphere CP_1 as a fiber. The twistor structure is induced from the product of $T(M^4) \times T(CP_2)$ of twistor spaces $T(M^4)$ $TC(P_2)$, which are the only twistor spaces allowing Kähler structure. The induced twistor structure and determined by an action principle with is 6-D Kähler action existing only for M^4 and CP_2. Twistor structure requires dimensional reduction so that one bundle structure and the action reduces to a sum of a volume term having interpretation in terms of cosmological constant and of 4-D Kähler action as analog of Maxwell action.

   PEs realizing the holography are identified as minimal surfaces [L79], which, apart for lower-dimensional singularities, are also locally extremals of the 4-D Kähler action and possess a holomorphic structure reducing the field equations to algebraic conditions analogous to Cauchy-Riemann conditions. One can regard the space-time surface as an analog of soap film spanned by frames assignable to the singularities at which minimal surface property fails but extremal property for the entire action remains true so that conservation laws are not lost. As in the case of ordinary soap films, frames are seats of finite non-determinism interpreted as space-time correlates of quantum non-determinism.

3. The concrete study of the extremals of the action principle leads to the identification of the basic candidates for the basic PEs. From the point of view of TQC, magnetic flux tubes are the most interesting objects and define counterparts of the braid strands. The notion of magnetic body (MB) is central. Its detailed identification is still far from complete: for the latest view about gravitational MB see [L85].

Physics as a generalized number theory and $M^8 - H$ duality

Physics as (a generalized) number theory is the dual vision of TGD.

1. p-Adic physics emerged originally from a model for the particle massivation based on p-adic thermodynamics for the mass squared of the particle [K55, K24]. From the beginning it was clear that various p-adic physics had to be fused with the real number based physics to a larger framework, which could be called adelic physics. For mathematical reasons, the natural interpretation of various p-adic physics would be in terms of physical and mathematical correlates of cognition. Number theoretical universality stating that the basic equations of TGD are number-theoretically universal and make sense in all number fields is a natural constraint on the theory.

2. $M^8 - H$ duality [L53, L54] realizes the number theoretical vision about TGD and also holography. M^8_c identified as complexified M^8 and interpreted as complexified octonions, is analogous to momentum space and 4-surfaces define the basic objects at the level of M^8.

   The 4-surfaces in M^8_c (complexified M^8), which have an interpretation as complexified octonions, are required to be associative in the sense that their normal space is quaternionic. These 4-surfaces are determined by the roots of polynomials of real argument continued to polynomials in M^8_c. The roots define a collection of 3-D mass shells of $M^4_c \subset M^8_c$ and by holography they define a 4-D surface of M^8_c. Physical states correspond to 4-momenta at these mass shells analogous to Fermi balls.

   $M^8 - H$ duality, analogous to momentum-position duality, relates the two visions by mapping the 4-surfaces in M^8 to those in H. $M^8 - H$ duality generalizes to the level of twistor space [L53, L54, L77, L80, L81].

3. One can assign to a given polynomial an algebraic extension of rationals. The collection of points of the 4-surface of M^8_c defines a cognitive representation. The mass shells as sources of holographic data are however number theoretically exceptional in that the number of points with algebraic M^8_c coordinates is infinite: cognitive explosion takes place both at the level of

M^8 and H: these values of the light-one proper time a correspond to very special moments in the life of self, kind of moments of enlightenment.

In M^8 the points of mass shells are identifiable as quark momenta assumed to be algebraic integers just as ordinary momenta for particles in a box are integers with suitable choice of momentum unit. These momenta can also be interpreted as points in extension of p-adic numbers so that number theoretical universality follows. The p-adic prime in question is identified as the largest ramified prime of the extension considered.

This gives rise to a hierarchy of algebraic extensions and cognitive representations as unique discretizations of the 4-surface in M^8 and space-time surface and suggests a generalization of computationalism replacing integers with the hierarchy of algebraic integers for extensions of rationals.

4. The dimension n of algebraic extension is identified as an effective Planck constant $h_{eff} = nh_0$ where $h_0 < h$ is true. The identification of the value of n_0 in $h = n_0 h_0$ has been proposed [L72]. The phases of ordinary matter labelled by the value of n behave in many respects as dark matter and the identification as dark matter has been proposed. A particularly important class of phases corresponds to $h_{eff} = nh_0$. These phases would play a central role in living matter. The relationship with galactic dark matter is however somewhat unclear.

   What makes these phases so important is the scale of quantum coherence is expected to scale like h_{eff}. Dark phases are also expected to have very weak interaction with ordinary matter and the proposal is that living matter is controlled by this kind of phases located at MB and approaching only slowly thermal equilibrium with it: this would have interpretation as aging [L134]. The small value of h and thermal fluctuations spoiling quantum coherence and entanglement belong to the key problems of QC and dark matter could solve these problems.

5. Galois confinement [L64] states that physical states have total momenta, whose components are ordinary integers. Galois confinement provides a universal mechanism for the formation of bound states. Galois confinement also applies in spin degrees of freedom and provides spin representations for the covering of the Galois group. The number theoretic degrees of freedom are of special interest in QC and suggest that number theoretic quantum computation (NQC) as a counterpart of TQC, which would involve what might be called Galois anyons. The Galois group could allow identification as a subgroup of the braid group. This would mean strong restrictions on TQC.

6. $M^8 - H$ duality leads to a view about the construction of the counterpart of S-matrix in the TGD framework [L80, L81]. S-matrix would be replaced by the analog of Kähler metric in fermionic degrees of freedom [L62], which by the infinite dimension of Fock space is expected to be highly unique as also the Kähler metric of WCW [K50, K25, K84].

   Incoming and outgoing states of particle scattering would be Galois singlets constructed from lower level states which need not be Galois singlets. Quarks, whose momenta at mass shells are algebraic integers are free and the scattering would be mere reorganization of Galois singlets to new ones.

   Scattering could be also seen as analog of QC and computation in an extension of rationals: both the input and output would consist of a set of rational integer valued momenta and scattering would map them to each other.

   This applies in the twistor picture also to spins having a representation as points of the twistor sphere S^2 known as Bloch sphere. In this case number theoretic constraints suggest that the set of quantization axes corresponds to a finite discrete subgroup of $SO3$) assignable to regular polygons and Platonic solids.

   The quark momenta belonging to the extensions of rationals are invisible, which implies invisible algebraic complexity of cognition and brings in mind unconscious information processing. Quantum physics and psychoanalysis would meet!

6.1.2 Zero energy ontology (ZEO) and QC

The first basic motivation for the introduction of ZEO was that by the general coordinate invariance space-time surface as a preferred extremal is a more natural notion than 3-surface. For exact holography, these notions are equivalent but the identification of space-time surface as minimal surface predicts a small violation of the strict holography identifiable as a correlate for quantum non-determinism associated with the physics of cognition or possibly quite generally. This non-determinism would be essential for the possibility of TQC in TGD.

Second motivation was the basic problem of quantum measurement theory to which ZEO provides an elegant solution if one assumes that the arrow of time changes in "big" state functions reductions (BSFRs) as analogs of ordinary SFRs. In "small" SFRs, which are analogs of "weak" measurements introduced in quantum optics, the arrow is not changed [K113] [L52, L73].

In the TGD framework, quantum measurement theory generalizes to a quantum theory of conscious experience in which SSFR defines the basic element of conscious experience. BSFR has an interpretation as a counterpart of death/sleep. The change of the arrow of time in BSFRs has profound implications in quantum biology. Since the dissipation with a reversed arrow of time for a subsystem looks like self-organization from the point of view of a system with an opposite arrow of time [L51]. The arrow of time can change for macroscopic time periods at the MBs with large h_{eff} and since MB controls the ordinary matter, it induces not only effective quantum coherence but also an effective reversal of time also at this level.

The basic ideas of ZEO [L52, L73] are following.

1. In zero energy ontology (ZEO) [L52, L73], the pair of incoming and outgoing states of particle scattering are replaced with zero energy state and zero energy states define scattering amplitudes as entanglement coefficients.

2. At the level of H, positive and negative energy parts of zero energy states are located at boundaries of causal diamonds (CD), which form a fractal hierarchy. At the level of M^8, they reside at the boundaries of mass shells, which corresponds to the roots of the polynomial defining the space-time region. M^8-H duality maps these points to the boundary of CD. One can also consider an alternative for which mass shells as hyperbolic spaces $H^3 \subset M^8$ are mapped to their counterparts in H by a map which is essentially inversion (Uncertainty Principle).

3. Scattering events [L80, L81] are QC like events. Input (output) data correspond to incoming (outgoing) quark momenta identified as algebraic integers in an extension of rationals and to spins. Since fermionic Fock state basis defines a Boolean algebra, the fermionic states define quantum analog of Boolean algebra, and the scattering amplitudes could be also seen as a quantum generalization of Boolean maps and realizing statements which are true that is consistent with laws of physics. These transitions could be interpreted in terms of Boolean cognition.

   The replacement of the S-matrix with Kähler metric in fermionic Hilbert space degrees of freedom represents a new element. The analog of unitary transformation is assigned with CD and from the point of view of QC, CD could be interpreted as an embedding space analog of gate. Since gates allow control bits not affected by the unitary transformation, also the Boolean functions, which are not 1-1, can be realized as unitaries. Same is expected to be true also now.

4. The scattering amplitudes correspond a tensor net-like structure. Physical states are Galois singlets consisting basically of free quarks. At the number theoretical level, scattering can be seen as a recombination of Galois singlets to new ones.

ZEO could have a profound impact on QC.

1. Negentropy Maximization Principle (NMP) [K58] [L71] is the variational principle of TGD inspired theory of consciousness. Negentropy can correspond to the sum of p-adic negentropies or to the sum or p-adic and real negentropies, which can be possible and tends to be so by NMP. For both options, NMP guarantees that the p-adic entanglement negentropy increases and is positive. It however also forces the real entanglement entropy to grow. NMP therefore implies cognitive evolution but also second law.

   From the point of view of QC, this picture is very promising since the laws of physics would take care that the entanglement negentropy grows and also that negentropic entanglement tends to be stable. This is quite contrary to what standard physics predicts. This leads to evolution [L34, L35] in the sense that the dimension $n = h_{eff}/h_0$ of the extension of rationals as a measure of algebraic complexity tends to increase since this provides larger negentropic resources. This evolution takes place at MB in human length and time scales and the challenge is to learn to manipulate dark matter.

2. BSFR could take care of error correction automatically since for the reversed arrow of time dissipation looks like error correction by self-organization. This error correction is a key feature of living matter but has remained poorly understood. One can also ask whether BSFRs could make possible QCs involving sub-QCs in both time directions. Could the use of sub-programs with opposite time direction allow a faster QC.

6.1.3 Finite field approximation and QC

Number theoretic vision about QC leads to new ideas about QC itself.

1. The momenta in the extension of rationals as algebraic integers can be interpreted as p-adic integers in the induced extension of p-adic numbers. The p-adic number field corresponds to prime p, which is the maximal ramified prime for the polynomial in quesetion.

   In the approximation $O(p) = 0$ they define a finite field $F(p,n)$ having dimension is is not larger than the dimension of extension but can be smaller. The number of elements is p^n and the situation corresponds to n pinary digits, qupits, instead of qubits. TQC using elements of $F(p,n)$ is an attractive possibility. Besides this one has also spin degrees of freedom.

2. The elements of $F(p,n)$ can be regarded as roots of some, in general non-unique, polynomial with degree p^n. This polynomial is in general not the polynomial inducing the extension of p-adic numbers.

3. The Galois group for the finite field should transform to each other the roots of the originalpolynomial interpreted as a polynomial in $F(p,n)$ and is a subgroup of the Galois group for the polynomial having all points of $F(p,n)$ as its roots.

The automorphism group of quaternions is analogous to Galois group and in the TGD framework with discretization it looks like a natural notion.

1. In the continuous case, the automorphism group of quaternions is the rotation group $SO(3)$ having $SU(2)$ as covering group. In the discrete situation, one expects it to be a finite group and would correspond to symmetries of Platonic solid in non-abelian case and to the symmetries of a regular polygon in abelian ase. Icosahedron, tetrahedron, and octahedron have triangles as faces and the proposal is that genetic code realized in terms of bioharmony [L7] [L58] corresponds to so called icosa-tetrahedral tessellation of H^3 [L69].

2. Therefore genetic code and bioharmony could closely relate to the quaternionic aspects of number theoretic physics and perhaps also to TQC for quantum variant $SU(2)_q$ of quaternionic automorphisms acting in the normal space of the space-time surface. A natural proposal is that the points of the icosahedron and tetrahedron correspond to points for the discretized unit sphere known as Bloch sphere defining possible directions of the quantization axis of spin in TQC.

3. The finite subgroups of $SU(2)$ are associated with the hierarchy of inclusions of hyperfinite factors of type II_1 and the proposal is that the inclusion of these factors define finite measurement resolution such that the included factor defines the resolution [K110, K40].

6.1.4 TQC and the new view about space-time

The new view about space-time is highly relevant for the TGD view of TQC.

Galois anyons

The basic problem of the TGD inspired model of TQC is the identification of the topological qubit identified as an anyon-like state in standard TQC. One could say that topological qubit or its analog does not correspond to quantum state but representation of braid group or quantum group assignable to Chern-Simons action. Topological qubits also satisfy a nice algebra defined by the decomposition rules of the representations of the braid group.

The motivation for this identification is that topological qubits are expected to be highly stable since the change of the representation is not expected to be probable unlike the change of spin direction. The non-local character is also an important aspect. The braids defining TQC program as unitary representation of the braid group allows to identify the gates, which are universal in the sense that they have finite computational accuracy.

The increase of the order of the covering group as a finite covering of the permutation group S_N for N braid strands allows to improve the accuracy. Kitaev [B8, B7] has proposed [D19] that anyon-like bi-localized states of condensed matter Majorana fermions could define stable qubits. Majorana electrons would be superpositions of electron states localized at the ends of a superconducting wire and would have parity $+/-1$ under permutations of ends of the wire.

In TGD framework the electrons defining analogs could be bi-localized states with localization to the ends of a monopole flux tube or pair of them. Galois degrees of freedom are a new element and anyons could correspond to multi-localized states defining representations of Galois group at its orbits consisting of points of the cognitive representation at mass shell H^3. Also spin degrees of freedom would define Galois representation. If the braidings correspond to lifts of number theoretic symmetries, Galois group corresponds to a subgroup of the braid group.

In the standard picture of TQC, a computationally interesting situations corresponds to non-Abelian anyons to guarantee that the states defining topological qubits form a higher-D space. This means that the swap $ab \leftrightarrow ba$ is not a commutative operation inducing a mere phase anymore. Since the status of Majoran fermions is unclear, it is still unclear whether any anyonic system satisfies this constraint. Galois groups are in general non-commutative so that this problem disappears.

Physical states would be Galois singlets and anyon-like states would be their building bricks just as quarks would define building bricks of general Galois singlets including also leptons and various bosons. Since Galois non-singlet cannot appear as a free particle, one could also understand topological entropy associated with anyons as relating to the entanglement with environment forced by Galois singletness in spin degrees of freedom.

Braidings and reconnections as basic elements of TQC

TQC in the TGD Universe involves also other new elements besides Galois groups.

1. The flux tubes connecting the nodes of a tensor net-like structure define natural candidates for braid strands. Both space-like and time-like braiding are possible.

   Time-like braiding defining TQC of the moving nodes connected by flux tubes induces a space-like braiding so that the TQC is recorded to memory as a kind of log file. Dance metaphor expresses this neatly: dancers at the parquette are connected by threads, which get braided and form a memory representation about the dance. This mechanism could define quite a general representation of memories based on space-time topology.

2. The fusion defined by the tensor product for the representation of the braid group or associated quantum groups is a key operation in standard quantum computation. The decomposition of the tensor products gives a superposition of topological qubits or more general qubit-like entities An interesting question is whether the fusion could have a more concrete topological meaning. Could the fusion of flux tubes correspond to a formation of a bound state of flux tubes inside a flux tube?

3. TQC as a braid generalizes to tensor-net (for tensor nets in TGD sense see [L17] [L26]). The nodes can have M incoming qubits and N outgoing qubits. The node corresponds to a quantum computation defined as a map between the incoming and outgoing qubits. In the framework, the nodes would correspond to CDs For $M \neq N$ is not a unitary transformation 1-1 transformation but can be an injection so that it is still an isometry at the level of the state space.

4. Besides swap as the basic braiding operation, also reconnection, having the same effect as far as initial and final states are considered, appears as a basic operation. When the incoming and outgoing qubits cannot move, reconnection could take the same role as swap and make TQC possible.

5. One can wonder whether this more general view about TQC could be realized in quantum biology. Could biochemical reactions correspond to fusions of braids of a tensor net, could reconnections and braidings make it possible to have a larger repertoire of TQCs. Could ZEO-based error correction requiring only time reversal play a key role in TQC.

Different TGD based views of TQC

TGD suggests several different perspectives of TQC.

1. In the flux tube picture, the basic elements are braiding, reconnections and fusions in which flux tubes could even form a bound state inside a larger flux tube so that the fusion could have a geometric meaning. At the level of H, fusion could correspond to a process in which the incoming particles arriving into the CD form a tensor product. Inside CD fusion occurs and gives rise to a decomposition of irreps. Measurement selects one irrep first and outgoing states are obtained by an SFR cascade reducing the total Galois group to the factors defined by relative Galois groups by a cascade of SSFRs defining cognitive measurements.

   Dance metaphor implies a mechanism of memory with spatial braidings representing spatial braidings. This mechanism would be realized in all scales and define kinds of topological Akashic records. If reconnection is equivalent with swap operation, then TQC is also possible without braiding induced by the motions of braid ends.

2. CDs are counterparts of gates at the level of H and define a fractal hierarchy of gates with sub-CDs defining sub-modules.

   Space-time surface in H can be also seen as a 4-D soap film with frames as seats of non-determinism and one could assign mental images with this non-determinism. This suggests that the gates at space-time level correspond to the frames whereas CDs would correspond to entire TQCs at the level of H. This also suggests that TQC in the TGD sense must allow intermediate SSFRs at the frames. The situation is far from obvious since fractality is also present and involves a hierarchy of CDs.

   The M^8-H-duality provides a further view about TQC. A highly attractive idea is that TQC programs can be constructed as functional composites of polynomials giving rise to extensions of extensions of .... and inclusion hierarchies of corresponding Galois groups, each defining a normal subgroup of its sup-group.

   The normal subgroup hierarchy makes it possible to understand cognitive measurements as SSFR cascades reducing the representation of the Galois group to a product of representations for the subgroup and normal subgroup associated with it. This decomposition could generalize the decomposition of the anyonic representations. This would also suggest a deep connection with the paradigm in which computations are functions.

6.2 What could the replacement of the braid group with the Galois group mean?

The replacement of the braid group acting on anyons with the Galois group looks a rather innocent proposal first but has profound implications. The reason is that the Galois group permutes the roots of the polynomial P, which correspond to different mass shells in M^8 and therefore different values of light-cone proper time in H.

6.2.1 Functional composition of the polynomials and many-particle states

Functional composition of the polynomials is proposed to give rise to many-particle states.

1. The roots of P correspond to mass shells. Quarks have momenta at these complex mass shells. Roots and corresponding momenta are in general complex algebraic numbers and total momenta and mass squared values are real by Galois confinement.

2. Functional composite $P = P_n \circ ... \circ P_1$ of polynomials defines the interactions of particles in the number-theoretical picture. Functional composites are proposed to define particles as many-quark states and further functional compositions make it possible to engineer many particle states formed from these.

3. One can also consider iterates of a polynomial as analogs of many particle states involving only a single kind of particle. Functional decomposition gives as roots inverse iterates of the roots of the polynomial Q in $P = Q \circ Q ... \circ Q$ [L56, L80, L81]. Asymptotically they give rise to an analog of the true Julia set (`https://mathworld.wolfram.com/JuliaSet.html`) as a boundary of the filled Julia set. The inverse iterates near the boundary of the Julia set would correspond to very nearly the same mass squared values and thus proper time constant hyperboloids.

4. One can regard the roots of P_i as roots with respect to the variable $y = P_{i-1} \circ ...P_1(x)$ if $y = P_{i-1} \circ ...P_1(x)$ defines the ground state coordinate. $h_{eff} = n_0 h_0$ would define a natural ground state for which $h_{eff} = nh$ would hold true.

5. If the polynomials appearing in the composite satisfy $P_i(0) = 0$, one has "inheritance of roots". The roots y_i of P_i are mapped to their inverse images $(P_{i-1} \circ ...P_1)^{-1}(y_i) = P_1^{-1} \circ P_2^{-1} ... \circ P_{i-1}^{-1}(x)$. This inheritance brings in mind conserved genes. A weaker form of "inheritance" would be that some polynomials, say $P_1, P_2, ..., P_k$ at the lowest level have $P_k(0) \neq 0$. For $P = Q \circ P_F$, where $P_F = x^2 - x - 1$ is "Fibonacci polynomial", the roots would be of form $(-1 \pm \sqrt{5 + 4y_n})/2$, where y_n is a root of Q. Note that one has $P_1(0) \neq 0$. If one has $P_k(0) \neq 0$ for $k > 1$, the roots of P_1 are roots of any P and therefore universal. This suggests the possibility that the ground state polynomial corresponding to $h_{eff} = h = n_0 h_0$ is non-vanishing at origin.

Ground state polynomial

The ground state polynomial P_g corresponding to $h_{eff} = h = nh_0$ is of special interest physically.

1. The arguments allowing to deduce the value of n_0 in $h = nh_0$ lead to a conclusion that the ground state polynomial P_g [L72] corresponding to $h_{eff} = h = n_0 h_0$ corresponds to a Galois group with $7!^2$ elements.

2. This allows several options. For instance, the semidirect product $S_7 \rtimes S_7$ could act as a Galois group. S^7 decomposes to a semidirect product of the simple alternating group A_7 and Z_2 acting as a normal group. S_7 can appear as a maximal Galois group for a polynomial of order 7. In this case S_7 could correspond to $Q_a = P_7 \circ P_2$ or $Q_b = P_2 \circ P_7$ and one would have four options $P = Q_i \circ Q_j$. Also $P_7 \circ P_7 \circ P_{2,a} \circ P_{2,b}$ $P_{2,a} \circ P_{2,b} \circ P_7 \circ P_7$ are possible.

3. Second roots appear in all basic formulas of quantum mechanics. Therefore one can argue that P_2 should appear at the bottom of the composite polynomial defining the ground state. Fibonacci quantum computation involves Golden Mean and the roots $x_\pm = (-1 \pm \sqrt{5})/2$ of Fibonacci polynomial $P_F(x) = x^2 - x - 1$. All roots would appear as pairs with members related by the Galois group of P_F. For $P_1 = P_F$ and $P_k(0) = 0$ for $k > 1$ (inheritance), the roots of P_F are roots of any P and Golden Mean would play a key role in fundamental physics.

Mass squared formula and inheritance hypothesis

For Galois singlets, the total momentum has components, which are ordinary integers. Also mass squared is integer.

1. If the stringy mass formula $m^2 = n$ holds true for the quark mass squared values as roots of a polynomial, one must have $m^2 = \sum m_i^2 = n$. This requires that the sum of the inner products

of quark momenta vanishes. The interpretation would be as an additivity of conformal weights. If every root is realized as quark momentum, $m^2 = \sum m_i^2$ equals the constant coefficient of the total polynomial P giving $m^2 = P(0)$.

2. If the strong form of inheritance holds true, one has $\sum m_i^2 = 0$ so that the total conformal weight vanishes. Could the interpretation be in terms of conformal invariance? Could one say that the tachyonic total mass squared assignable to the space-like states defined by braid strands compensates for the non-tachyonic total mass squared?

   Total momentum would be light-like and the $M^8 - H$ duality should be defined as the map $p^k \to m^k = \hbar_{eff} p^k/(p^0)^2$ where m^k belongs to the light-like boundary of CD containing the CDs assignable to the mass squared values as sub-CDs.

3. In p-adic mass calculations the total conformal weights are however non-vanishing and real. What could this mean?

   (a) The thermal excitations should be excitations of the $m^2 = 0$ state due to interaction with the environment, which extends the system. The thermal excitations would be described by polynomials $Q_{ex} = P_{ex} \circ P$. The roots of Q_{ex} would include, besides roots of P (inheritance), also the roots y_n of P_{ex} and these correspond to non-vanishing values of $P(y_n)$. $y_n \neq 0$ would give non-vanishing mass for the thermalized subsystem defined by P.

   (b) If one gives up the "inheritance" hypothesis and allows $P_i \neq 0$, one has $m^2 = \sum m_i^2 = P_n(0)$. Monic polynomials $P(x) = x^n + a_{n-1}x^{n-1} + ... + a_0$ are good candidates for the allowed polynomials. The coefficients a_k are integers so that the mass squared as a conformal weight $\sum m_i^2 = a_0$ is an integer.

Decomposition of Galois group to a product of relative Galois groups

The Galois group Gal for an extension of extension.... decomposes to a product of the relative Galois groups Gal_k/Gal_{k-1}.

1. One can speak of the ground state characterized by some Galois group Gal_0. Ordinary Planck constant h would correspond to Gal_0 and in [L72] it was proposed to be a product of permutation groups S_7 giving $n_0 = (7!)^2$. This allows to interpret CP_2 length scale squared as $n_0 l_P 2$, l_P Planck length. Galois group can be identified as a relative Galois group: as Galois group for extension of the extension defining the ground state.

2. The structure of the Galois group reflects the functional composition involving a large number of identical polynomials with the same mass spectrum as free particles. In the functional composite $P \circ Q$ the mass spectrum S of P is mapped to $Q^{-1}(S)$. Large number of iterations of P produces Julia set as a fractal. One can speak of an asymptotic mass spectrum.

3. The orbit of Galois group consists of mass shells and its cognitive representation can contain momenta at these mass shells.

   Galois symmetry would be a discrete symmetry connecting quarks with different mass values (which are counterparts of virtual masses rather than real masses). Galois symmetry would be analogous to a dynamical symmetry and would not commute with Poincare and Lorentz symmetries.

   Physical states are Galois singlets and have well defined real mass squared. Galois singlet property of physical states would imply that these symmetries would be respected. Physical states correspond to a CD containing sub-CDs... and at the lowest level there would be quarks. Essentially 4-D objects would be in question.

6.2.2 $M^8 - H$ duality at the level of M^4

$M^8 - H$ duality maps the algebraic physics at the level of M^8 formulated using polynomials to the geometric physics at the level of $H = M^4 \times CP_2$ formulated using variational principle and partial differential equations. The preferred extremal property required by general coordinate invariance reduces the number of solutions of field equations so that they can correspond to a much smaller set of solutions of algebraic equations. The holographic aspects of $M^8 - H$ duality have been already considered and in the following only the map $M^8 \supset M^4 \to H \supset M^4$ is discussed.

1. $M^8 - H$ duality maps the surfaces of M^8 to minimal surfaces in H having singularities at which only the field equations for the full action containing also Kähler action besides the volume term hold true. $M^8 - H$ realizes holography: the mass shells determined by the roots of P can be continued to 4-surfaces containing them.

2. The precise form of $M^8 - H$ duality is not quite clear. The first question is whether one should allow complexification of M^4 as at the H side. One could define the H image as $M^k = \hbar_{eff} Re[p^k/m^2]$, where p^k is the quark momentum and at mass shell m^2. M^k would define some geometric objects in H. For physical states m^2 is integer and corresponds to a finite value of $a = \hbar_{eff}/m$. If the stringy mass formula $m^2 = \sum m_i^2 = 0$ is true, the image belongs to the light-cone boundary.

   The image could be a geodesic line of H parallel to m^k, which could start from the origin from the common center of CDs forming a fractal Russian doll hierarchy or from the tip of a given sub-CD.

   The image could also be identified as a point or a set of points. The point could be identified as the intersection of these lines with the boundary of the sub-CD defined by the mass value or its real part. Also the intersections with boundaries of all sub-CDs involved can be considered. Also the map of mass shells to M^8 to hyperboloids $a = a_n$, where a is light-cone proper time and a_n is inversely proportional to mass to realize Uncertainty Principle, makes sense.

3. The image of the orbit of the Galois group would correspond to a geodesic line starting at the centers or tips of various CDs defined by the mass shells. If the CDs are inside each other like a Russian doll, the geodesics intersect the $a = a_n$ hyperboloids and the boundaries of corresponding sub-CDs corresponding to different values of the light-cone proper time a and are time ordered. What is highly non-trivial is that the points at the orbit have time- like distances.

6.2.3 The orbits of the Galois group in H transform hyperboloids to each other

Mass squared values correspond to the roots a_n of a polynomial and are in general complex algebraic numbers. Their real projections can be negative and therefore tachyonic. The big surprise during writing of this article was the trivial observation that the Galois group permutes the mass shells defined by the roots of P.

If the real projections of mass shells to M^4 are mapped to H, Galois group can connect points with different values of complex "cosmic time" $a = a_n$. This does not conform with the idea that the particles of the physical state always have space-like distance but could conform with ZEO and non-determinism inspiring the view that time-like braiding is a physical state rather than its time evolution.

Note however that the spatial distance $(M_1 - M_2)^2$ in H is space-like for $(E_1 \geq m_1^2 + m_2^2)/m_2$ in the coordinate system in which M_2 and p_2 have a vanishing spatial part. This holds true also for the M^4 images.

Orbits of the Galois group as braidings?

Could the orbits of the Galois group for off-mass shell states be identified as braidings?

1. If the braiding is time-like, the value of the real part of the proper time parameter corresponding to the mass shells or CD sizes increases along the orbit.

   This would conform with the idea that the orbit of the Galois group consists of images of mass shells at the quark level. It also conforms with the breaking of Lorentz and Poincare symmetries at the level of the Galois group. This finding also justifies the Galois confinement: physical states correspond to a single value of a.

2. What about number theoretic anyons? These anyons must have non-trivial Galois quantum numbers and algebraic momenta. Here the relative Galois group is a convenient concept. Galois non-singlet property is with respect to the relative Galois group and one can forget the huge complexity of the Galois singlet ground state altogether.

Do Galois anyons require tachyonic states?

The momenta of quarks define the basic representation of the Galois group. One can also imagine representations in spin degrees of freedom. If only the spin degrees of freedom carry Galois quantum numbers, the space-time action of the Galois group is trivial. This does not look attractive and does not conform with time-like braiding. Anyon property therefore suggests the presence of tachyonic momenta.

1. I have played with the idea that quarks and also weak bosons appear in the scale of cells in living matter as dark quarks or even scaled variants with very small mass. How could the dark quarks manifest themselves?

   I have proposed that the protons of dark nucleon triplets representing codons are connected by meson-like bonds, which could be colored and confine codons to genes. This could the case also for the bonds connecting nucleons in the ordinary nuclei. Strong interaction would also make it possible to have dark neutrons.

   I have assigned the Z_3 Galois group with the dark nucleon triplets defining dark codons: this is required by the correct statistics in the model of the genetic code. Could Galois group Z_3 correspond to the center Z^3 of the color group $SU(3)$?

2. In the original proposal for DNA TQC [K3], quark triplets were indeed considered instead of dark nucleon triplets. Dark tachyonic electrons assignable to symmetric hydrogen bonded structures looks like a more realistic option. One can also consider mesons with quark and antiquark ends associated with the ends of the space-like braid strands. Dark tachyonic electrons could be associated with the ends of string world sheets for which the time dimension corresponds to a space-like normal dimension.

   Could one assign a colored quark pair to anyon-like electron? Leptohadrons [K104] are a basic prediction of TGD and there is empirical evidence for them. The predicted mass of the lepto-electron is very nearly the same as electron mass and evidence for its existence was found already in the seventies. Lepto-electron would be a color octet: this is allowed in the TGD framework.

   Lepto-hadron is associated with the breaking of parity symmetry in nuclear collisions involving strong electric and magnetic fields not orthogonal to each other. Its description involves Chern-Simons Kähler action associated also with anyons. The notion of induced gauge field allows its interpretation as SU(3) Chern-Simons action. A possible identification of lepto-electron would be as an anyon for which electron would be accompanied by a color octet quark pair formed by the quarks at the ends of the flux tube.

3. Polynomials can also have roots corresponding to space-like mass squared values. Could dark quarks be tachyonic in the sense that they have a negative real part of mass squared so that time direction as a normal direction for this object would be naturally space-like?

4. Could one see time-like braids structures as genuinely 4-D objects predicted by ZEO and the failure of the strict determinism of the action principle? Singularities as frames span 4-D soap films serve as a source of non-determinism.

How could dark DNA correspond to time-like braids strands for dark DNA?

The following represents a long list of cautious proposals represented as questions.

1. Can one Galois symmetries acting in time direction have projections acting effectively as 3-D symmetries of ordinary matter at time=constant surface.

   The Galois group at the level of (presumably gravitational) MB does not act at the level of ordinary matter. Could the time-like braids at the level of the dark DNA correspond to the ordinary DNA strands in the sense that the temporal sequences would be mapped to spatial sequences by some simple rules?

2. Could genes have a representation as time-like braids? Could one imagine a pile of or ordinary DNA strands and their dark counterparts at different values of $a = a_n$ such that time like braid strands would have the same DNA content as the DNA in $a = constant$ or $t = constant$ plane. For instance, could the intersections of the points of cognitive representation at $a = a_n$ hyperboloids with $t = constant$ hyperplane define the DNA strand.

   The codons of dark DNA as a temporal sequence would correspond to codons of the ordinary DNA unless one assumes that only identical codons correspond to the orbits of the Galois group. This looks like a more reasonable option. Codons themselves would correspond to orbits of the discrete and finite subgroups of automorphisms of quaternions acting as symmetries of Platonic solids and regular polygons. Therefore two kinds of Galois groups would be involved.

3. Could the physical DNA correspond to the space-like braidings assignable to the time-like braidings of dark DNA? Could one realize the representations of the Galois group by using these projections at the level of ordinary DNA.

4. Could identical codons of a gene correspond to projections of points related by the Galois group? If so, the collections of identical codons (64 of them) would correspond to 64 orbits and the anyons would be realized at these collections as wave functions. Different representations would correspond to different anyons serving as number theoretical qupits.

String world sheet interpretation of time-like braidings at the level of H

$M^8 - H$ duality implies time-like braids correspond to physical states rather than time evolutions of an ordinary physical state localizable to time= constant hyperplane. The time-like character of states conforms with ZEO and is implied by the predicted non-determinism in which the singularities of the minimal surface correspond to loci for the failure of strict determinism. These singularities define analogs of frames for the space-time surface as an analog of a 4-D soap film. They are a necessary part of the data allowing to realize holography.

$M^8 - H$ duality [L53, L54] predicts candidates for the singularities as loci of non-determinism. The following argument suggests that the 2-D orbits of braid strands defined by string world sheets as fundamental objects of the TGD Universe giving rise to braidings could characterize the non-determinism.

1. 3-D light-like surfaces defining orbits of partonic 2-surfaces starting at the boundaries of CD and 2-D string world sheets connecting two light-like 3-surfaces. Strong form of holography, whose status is uncertain, states that only the partonic 2-surfaces at the boundaries of CD are needed.

2. String world sheets would provide additional data to fix the preferred extremal and the failure of 4-D determinism manifested as the failure of the minimal surface property would be localizable to the string world sheets. According to the dance metaphor, the ends of the strings would represent dancers and strings would represent the threads connecting their feet.

   String world sheets would be necessary for fixing the space-time surface. This is a profound deviation from string models, where data at time=constant section would fix the time evolution.

   In fully deterministic physics, the direction of time coordinate is normal to $t = constant$ slice. The normal directions of the string world sheet are analogous to time direction:

that they are space-like conforms with tachyonicity. String world sheet would represent a tachyonic virtual particle exchange between particles with time-like momenta.

3. Also strings are minimal surfaces apart from singularities. Reconnection is a singularity at which the string world sheets intersect at a single point and involves failure of determinism. The effect of reconnection is the same as that of braiding (SWAP). Reconnection therefore corresponds to the SWAP gate in TQC.

4. The 4-D character of the space-time surface implies that the strings develop spatial braiding during the dance and can also reconnect. This does not happen in super string models with 10-D embedding space for strings.

   The braiding and reconnection patterns would represent the time evolution of string-like entries in 4-D space-time so that TQC would reduce to a string model-like theory with one important exception: braiding and reconnections are not possible in string models.

   Gravitational flux tubes would be one particular case of flux tubes. They seem to be key players in biology and provide a quantum gravitational view about metabolism, biocatalysis, and DNA [L85]. TQC involves braiding and flux tubes with strings attached with them: TQC would have a direct connection with string model type description of quantum gravitation and other interactions.

Tachyonicity of the time-like braids as physical states could be therefore understood. One can look at the situation also from the point of M^8-H duality to gain additional perspective.

1. Virtual particles of QFT picture would in TGD framework have a discrete mass squared spectrum give by the roots of a polynomial and thus algebraic, in general complex, numbers [L80, L81]. Their finite number in zero energy state would resolve the divergence problem of QFTs.

   Only quarks appear as fundamental fermions. Mass squared values and momenta of many quark states constructed are in an extension of rationals without the condition of Galois confinement implying stringy mass squared spectrum and integer valued momentum components using the scale of CD as unit.

2. Quarks at mass shells of $M^4 \subset M^8$ are mapped to geodesic lines of H by M^8-H duality. They can be also space-like unless one assumes that the real parts of the roots of P are non-negative. For negative real parts, the momenta would be space-like and define points outside the sub-CD but a larger CD could contain them.

   Could the total momentum of say 3-quark state possibly associated with codon (3N quark state associated with a gene) be tachyonic? Could the tachyonic quark triplets be located along the time-like braid strand associated with the codon and define a tachyonic many-quark states?

3. For anyons as tachyons Galois confinement must fail and they should correspond to virtual states made from quarks. Could the strands of a space-like braid as a string with quark and antiquark at its ends define an entity analogous to a virtual meson? Could this meson-like entity have non-trivial color quantum numbers?

   How do Galois confinement and color confinement relate? At the level of "world of classical worlds" (WCW) quark color corresponds to partial waves in CP_2 for cm degrees of freedom for the partonic 2-surfaces associated with quark. At the level of the space-time surface there are no color partial waves since fermions do not have color as a spin-like quantum number. I have proposed a Z_3 subgroup of the Galois group as a counterpart for $Z_3 \subset SU(3)$. Correct statistics requires antisymmetry with respect to Galois Z_3.

   One must take this with caution: maybe the braid statistics of anyons could solve the statistics problem. Note however that braid statistics is analogous to Fermi statistics in that two particles are not possible in the same state.

The original proposal for DNA as a TQCer, was that DNA and nuclear membrane are connected by flux tubes having quark and antiquark at their ends. Also DNA strands would be connected by this kind of strands. The proposal was motivated by the observations and the classical counterpart of color gauge field is proportional to the induced Kähler form, and can define a coherent field in arbitrarily long scales.

I gave up this proposal a long time ago but it seems that this proposal had some seed of truth in it. Anyonic electrons replace quarks and antiquarks.

1. What comes in mind first is that the DNA strand and its conjugate involve, besides dark nucleon triplets, also dark quark/antiquark triplets forced by the time-likeness of the braiding regarded as a physical state in ZEO. This however leads to problems since dark nucleons are strongly favored. Doubling of the genetic code without need for it looks ugly. The mere quantum gravitational modification of the standard chemistry should be enough.

   Most importantly, tachyonicity does not require single quark states. Also the dark anyonic electrons could be virtual particles carrying tachyonic momenta. The 3+3 dark electrons assignable to the asymmetric HBs of form O..H-N would provide electronic realization of the genetic code. The dark codons would serve as names, addresses in the symbolic dynamics of TQC involving the resonance mechanism of communications requiring addresses.

   The dark anyonic electrons assignable with G-C bonds would carry tachyonic momenta and make the braiding possible. The tachyonic electronic momenta assignable to bonds symmetric O...H-O type bonds connecting water molecules and phosphates would be realized in the same way.

2. It is good to bring in mind the possible weak points of the scenario once again. Dark protons are strongly suggested by the Pollack effect and the proposed picture about dark gravitational HBs with delocalized dark protons [L85]. In the original view, dark protons screened the negative charge of phosphates. In the new picture the negative charge of phosphate is assignable with bi-localized (anyonic/dark/virtual) electrons of O...H-O +O-H...H: at the level of ordinary matter, DNA is not negatively charged. In QFT language, one might perhaps say that a dark electron is exchanged between the ends of the flux tube associated with the dark HB.

Connection with time-like character of music experience and cognition

A connection with the model of DNA based on bioharmony is suggestive.

1. DNA and RNA codons are identified as points at the orbits of icosahedral and tetrahedral subgroups of quaternion automorphisms. Amino acids (AAs) have been identified as orbits of the icosahedral and tetrahedral groups, which are discrete subgroups of quaternionic automorphisms, which is completely analogous to Galois groups.

2. Harmony is the basic element of music and music involves time in an essential way. Same is true of cognition. Perhaps the time-like braid strands could give a concrete content to the proposal. Codons would correspond to 3-chords and gene would correspond to a piece of music in a much more concrete way than originally proposed. Genes would also represent primitive cognitions.

6.2.4 Cognitive measurement cascades as counterparts of measurements of anyon charges

The measurements of topological charges reduce the tensor products for the representations of the braid group to irreducible representations. What would the counterpart for this process be at the level of the NQC?

1. I have discussed cognitive measurements [L13, L60] as a cascade of "small" state function reductions (SSFRs) for the irreducible representations of the Galois group of extensions of extensions of.... . The full Galois group has a representation as a product of relative Galois groups $R_n = Gal_n/Gal_{n-1}$. The SSFR cascade means a reduction of the representation to a product of representations of the relative Galois groups R_n.

2. This measurement cascade would be the opposite for the measurement of anyonic topological charges involving an analogous decomposition of the tensor product of representations to irreducible representations of the full braid group.

   In ZEO, the counterpart for the measurement of topological charges would correspond to the time reversal of this process starting with BSFR, which creates a completely entangled state as the representation of the full Galois group, and is followed by SSFR cascade proceeding in an opposite time direction. The formation and decomposition of tensor products would occur in different time directions.

6.2.5 Comparison of standard view about TQC with the TGD view

It is useful to compare the standard view about TQC with its TGD counterpart.

1. Qubits as states are replaced by representations of the braid group characterized by the value of the topological charge and of the quantum group G assignable to the Chern-Simons action.

   Quantum groups [A25, A6, A15] are discussed from the TGD point of view in [K14] and in chapters about possible role of von Neumann algebras known as hyperfinite factors of type II_1 in TGD [K110, K40].

   Quantum group $SU(2)_q$ quantum group characterized by quantum phase $q = exp(i\pi/k)$, $k = 5$, is the simplest option. One can say that anyons correspond to electrons assignable to the orbits of 2-D systems, whose time evolution could be described by Chern-Simons action.

   In TGD, these 3-surfaces would correspond to the light-like orbits of partonic 2-surfaces which for larger values of h_{eff} can have rather large size. For $h_{gr} = GMm/v_0$ the gravitational Compton length for a particle with mass m is $GM/v_0 = r_s/2v_0$ independent of the mass of the particle and for Earth this gives .45 cm for $v_0 = c$, one half of the Schwartschild radius.

2. Topological qubits correspond to topological charges such as the already mentioned parity for condensed matter Majorana electrons, which would have degenerate energies because they correspond to momentum vectors k and $-k$ differing by lattice momentum.

3. Quite generally, quantum measurements are Hilbert space projections. Measurement of qubit corresponds to a measurement of a topological charge. The qubit can be measured by a fusion process for the representations of the gauge group G. Fusion means a formation of a tensor product of representations and could result as a final state of TQC. Measurement means a projection to a particular representation characterized by a topological charge.

   One can also consider the opposite operation in which one decomposes a given representation to a direct sum of product representations and projects out one particular product representation by measuring topological charges for the composites.

4. Fibonacci TQC with quantum group $SU(2)_q$ for quantum phase $q = exp(i\pi/5)$, serves as the simplest candidate for an interesting TQC. Condensed matter Majorana fermions could correspond to Fibonacci anyons with $q = exp(i\pi/5)$ (`https://phys.org/news/2014-12-fibonacci-quasiparticle-basis-future-quantum.html`). The fusion for Fibonacci anyons is non-commutative and non-associative. These properties are coded by a non-commutative R matrix and non-trivial F matrix (see Appendix). For a fusion of N representations the number of degenerate ground states is N:th Fibonacci number.

This has a counterpart in TGD.

1. In the TGD framework, Galois group elements in general change the value of cosmic time as a real part of the root of the polynomial defining the mass shell in M^8 and its image in H. Therefore the associated virtual quark states are not energy degenerate.

   That mass squared values for anyons are different conforms with the idea of time-like braiding as a genuine quantum state rather than time evolution of quantum state, which is natural in ZEO. One can of course challenge this assumption. For states containing N particles with the same polynomial P and represented as an iterate $P \circ .... \circ P$ mass squared values as roots approach to Julia set for P, and this could give rise to approximate degeneracy of mass squared values and corresponding values of light-cone proper time a.

One can also consider a situation in which one has several roots with the same real part (say roots of a second order polynomial). One can ask whether the analogs of condensed matter Majorana fermions correspond to these kinds of states.

2. The topological structure in question would be realized in terms of the space-time topology as a monopole flux tube not possible in Maxwellian electrodynamics. Also the strings assignable to the flux tubes and corresponding string world sheets as representation of time-like braiding inducing space-like braiding would play a key role. Chern-Simons action would be assigned to the light-like 3-surfaces defining the orbits of partonic 2-surfaces and string world sheets would connect these orbits.

3. The quaternionic automorphism group, defining the analog of the Galois group and having $SU(2)$ or its quantum variant as a covering group, serves as the analog of the gauge group G and acts in the normal space of the space-time surface. Discrete and finite subgroups assignable to the Platonic solids and regular polygons define the natural finite discretizations of this group.

   The braid group could be replaced with a subgroup identifiable as the Galois group for an extension of rationals or for extension of extension of rationals. Also this group can be non-Abelian and would be naturally represented as a subgroup of the braid group.

4. Time reversed fusion corresponds to a cognitive measurement cascade consisting of unitary evolutions followed by SSFRs as counterparts of "weak" measurements. Cognitive measurement cascade and its reversal are initiated by a BSFR changing the arrow of time. Two subsequent BSFRs would correspond to fusion and its reversal and the time evolution between them would correspond to the braiding as a unitary evolution. In TGD inspired theory of conscious experience, the sequence of SSFRs gives rise to the flow of consciousness.

5. Quantum group $SU(2)_q$ for Fibonacci TQC has an interpretation as quantum automorphism. What makes this biologically highly interesting is that the twist $exp(i\pi/5)$ is realized geometrically in the structure of the DNA. This suggests that DNA and dark DNA could involve TQC. One can wonder whether genes with N codons correspond to a fusion of N Fibonacci representations.

6.2.6 Could the MB of DNA perform intentional TQC?

In TQC and also in AI as human endeavours, human intention plays a key role. This fact has been often forgotten by AI extremists. The braiding defining the TQC would be constructed using technological tools developed by humans. What about the situation at the level of DNA based TQC? Could the MB of DNA play the role of humans to some degree? What kind of quantum computations could the MB of DNA perform?

1. When the braid ends can participate in the flow defined by cellular water or by 2-D liquid defined by the lipids of the cell membrane in liquid crystal phase, one can consider the possibility that the MB induces this flow and in this way builds time-like TQC program, which is also stored as spatial braiding to memory.

   As will be found in the next section, this situation would be true for braids possibly defined by the gravitational flux tubes connecting the oxygens of phosphates of DNA with the lipid ends of nuclear or cell membrane containing also phosphates. Also the GTPs and GDPs of microtubules contain phosphates and their oxygens could be connected with those of lipid phosphates.

   The braiding would serve a memory storage purpose. If MB can induce the flow of water or of lipids, one can say that it can build TQC programs. For instance, a representation of function involving two registers could be constructed by starting from entangled register and using the flow of water or lipids to induce the needed braiding for the second register implying the entangled state $\sum |n\rangle\langle f(n)|$. The TQC ending with cognitive state function reduction cascade would define a conscious cognitive representation of the flow.

2. It will also be found that A-G base pairs by the N...H-N $\leftrightarrow$ N-H...N symmetry of gravitational flux tubes define candidates for HBs assignable to TQC. In this case the braid ends cannot move but the reconnections of braid strands could produce braiding and TQC. Similar situation is true for the sequence of identical DNA codons of, say, genes. They could define an orbit of the Galois group and give rise to its representation. There would be 63 types of orbits which could decompose to separate representations corresponding to various codons. Besides single electron states also many electron states would be possible.

   In this kind of situation, the cognitive measurement cascade would give rise to a conscious cognition at DNA level. In ZEO, reconnections would be forced by the preferred extremal property and unavoidable by the 4-D character of the space-time surface. Therefore they would reflect the underlying physics. The failure of the strict determinism could be interpreted as a selection between a finite number of alternatives at the frames defining the space-time surface as a 4-D analog of soap film. The analog of TQC would give rise to a sensory perception accompanied by cognition.

Factorization of integers into primes is one of the most interesting applications of QC. At first, it looks unlikely that the MB of DNA could be able to do something like this. However, finite groups have a prime decomposition to a product of finite groups and in the same way Galois groups have a decomposition to a product of relative Galois groups, which do not have a similar decomposition.

Group theoretical prime decomposition is analogous but more general than the prime decomposition of integers and more general composition of algebraic numbers to algebraic primes. Since groups with a prime number of elements are certainly prime groups, prime factorization would follow as a consequence and would be a side product of any cognitive SSFR cascade. This conforms with the paradoxical finding that idiot savants, who do not have any idea about the notion of prime, can factorize large integers [L23].

Could Quantum Fourier Transform (QFT) have any analog at the level of DNA? The states in the irreps of the Galois group serve as candidates for the plane waves defining Fourier components. Could cognitive measurements naturally involve a measurement of these quantum numbers as eigen values for maximal set of commuting Galois group elements acting as a minimal Galois transformation. For instance, a rotation by $exp(i2\pi/n)$ would be analogous to this kind of transformation in Z_n. These measurements would induce a localization to a single Fourier component and repeated measurements of the same state would give the probabilities of various Fourier components. These states are superpositions of states at mass shells with varying mass squared and involve time delocalization making sense by the finite non-determinism. A repeated measurement of Galois momenta would make it possible to find the factors of an integer as in the ordinary QC.

6.3 DNA as quantum gravitational TQCer?

In this section a detailed model for DNA as a TQCer will be developed. The attribute "quantum gravitational" is not necessary since also smaller values of h_{eff} than h_{gr} can be considered.

6.3.1 Concrete questions concerning DNA TQC

Before representing a concrete model for TQC using Galois anyons as qubits, the basic questions are discussed.

How could DNA qubits be realized physically?

For TQC temperature topological charge identifiable replaces spin as qubit. In the TGD framework Galois charges replace topological charges and one can talk about Galois anyons.

The basic question is how DNA makes it possible to realize anyonic qubits.

1. Dark nucleons associated with dark DNA codons, that is with O...H-O type HBs cannot realize dynamical qubits in terms of spin because the codons must be fixed if they are to represent genetic code. Only in the communications based on resonant cyclotron transitions

their states can temporarily change but should return back to the original state as a state of minimum (free) energy.

One can assign to A-T, G-C pairs 1+1 asymmetric HBs, which do not allow electronic anyons. This gives rise to 3 +3 dark electrons, which could give rise to dark representation of the genetic code.

The tentative interpretation is that the dark codons define the analog of computer hardware with a fixed ROM. The dark codons would serve as addresses in the resonance mechanism: the analogy with LISP is obvious.

2. The dynamical working memory should correspond to an anyonic realization of qubits. A dark electron associated with the quantum HB of type X...H-X +X-H...X can give rise to two bi-localized states with odd and even Z_2 parity where Z_2 exchanges the ends of HB. These two dark electron states could serve as anyons.

   This could work for electrons of O...H-O bonds between the oxygens of phosphate and water molecules. This could be also the case for the N...H-N bond of C-G base pair, which is symmetric. The HB can be assigned with C codon. In this case, the notion of Z_2 anyon makes sense and could make possible TQC using gravitational variants of symmetric HBs of C-G base pairs (`hhttps://cutt.ly/WGNddJ3`).

How could the unitary time evolution be realized?

Superpositions of HBs of type X...H-X + X-H...X could give rise to electronic anyons with bi-localized dark electrons. Depending on the situation, braiding or reconnections having, at least apparently, the same effect would define the unitary gates.

1. If the molecules containing X can move, braiding is possible. This is the case if the HBs are associated with the phosphates of lipids of the cell membrane forming a liquid crystal and connect them to the molecules of the cellular water. In the sol phase for intracellular water, the flow of water molecules could define braiding.

   The original proposal [K3, K105] was that the flux tubes connecting the oxygens of the phosphates associated with the DNA strand with the phosphates of the lipid ends would define TQCer. The flow of the lipids of the lipid layer forming a 2-D liquid could define a braiding and thus TQC program. For gravitational flux tubes this option could make sense. The oxygens of the phosphates of DNA could be also connected with the molecules of the water surrounding the DNA if they can move.

   In this case, the dance metaphor makes sense: the TQC as time-like braiding produces a log file as a spatial braiding.

2. For N..-H-H + N-H...N HBs of C-G base pairs the nitrogen atoms cannot move. The reconnections of dark braid strands could produce the same effect as braiding and induce flux tube connections between C:s and G:s belonging to distinct C-G pairs. For gravitational flux tubes these connections could be very long.

   String word sheets are fundamental objects in TGD and by the 4-dimensionality of the space-time surface, 2-D string world sheets at flux tubes representing the orbits of space-like braids intersect at a discrete set of points and for preferred extremals the reconnections are forced by topology. The non-determinism is associated with the choice whether the time-like strand pair AC+ BD transforms to AC+BD or AD+BC.

What about ordinary QC or TQC using electron spin of HB as qubit?

I do not understand TQC enough to say whether electron spin could also appear as a qubit when braidings and reconnections define the gates. In any case, this option meets the same objections as the QC option since a very low temperature would be needed in the standard physics framework.

1. The hyperfine splitting (`https://cutt.ly/oGNdeA3`), causing the 21-cm line of hydrogen, corresponds to the magnetic interaction energy of nuclear dipole moment with electron's magnetic field and is proportional to h_{eff}. The energy of hydrogen hyperfine splitting is

$\Delta E = 5.89 \times 10^{-6}$ eV. This corresponds to a temperature of 5.89×10^{-2} K. If the electrons are dark, the energy of hyperfine splitting is proportional to h_{eff}. The energy is above thermal energy at room temperature for $h_{eff}/h > 5 \times 10^3$.

Note that the temperature T at the MB of DNA is assumed to be very low but during aging identified as an approach to thermal equilibrium with the biological body T is assumed to increase and approaches the Hagedorn temperature assignable to the flux tubes of MB [L134].

2. If spin serves as a qubit, the manipulation of electronic qubits by changing their spin direction using photons or braiding or reconnection, which at least apparently seems to have the same effect as braiding, would be needed. Both braiding and reconnection involve the replacement $A \rightarrow C + B \rightarrow D$ with $A \rightarrow D + B \rightarrow C$ but reconnection involves temporary touch of the braid strands which might have some effect.

6.3.2 Number theoretical generalization of Kitaev's proposal

Kitaev [B8, B7] has proposed an elegant model for TQC using as qubits the two states of condensed matter Majorana fermion [D19] with two bi-localized states, which have parities +1 and -1 under Z_2 symmetry.

Galois group as subgroup of braid group and Galois anyons

In the TGD framework, the representations of the Galois group would naturally replace these representations and one could speak of TQC which is also number theoretic as far as anyon-like states are considered.

Topological robustness would be replaced by number theoretical robustness due to the fact that the extension of rationals depends only weakly on the polynomial: this is obvious from the fact, the number of extensions is finite for a polynomial of given degree. M^8-H duality [L53, L54] indeed implies that a given space-time region is determined by a polynomial. In QFT approximation one is forced to replace many-sheeted space-time with ordinary space-time and the nice picture is lost. One might however hope that in TQC this loss is fatal.

1. Galois group replaces Z_2. Instead of topological charges, one can speak of number theoretical charges. Representations of the Galois group would correspond to number theoretical qubits. Number theoretical anyon would be identified as a superposition of states localized at points of orbit of Galois group Z_2 associated with DNA double strand.

   As already found, the Galois ground state corresponding to $h_{eff} = h = n_0 h_0$ is not completely unique but would naturally correspond to a polynomial $P_g = Q_g \circ P_2$ where P_2 is second order polynomial, all roots of $P = P_1 \circ P_g$ appear in pairs $x \pm y$ and Z_2 permutes the members of the pairs. Fibonacci polynomial $P_F = X^2 - x - 1$ is highly attractive candidate for P_2 and would give the roots $(1 \pm \sqrt{5})/2$ as roots of all polynomials P. Also the twisting geometry of DNA favors Fibonacci TQC, which is also the minimal option.

2. Hydrogen bonds X...H-X and X-H...X are symmetric and their possibly gravitationally dark variants, could give rise to states with opposite parity. The electron of the hydrogen could define the number theoretic anyon.

3. The gravitational flux tubes as counterparts of H-bonds could define the braid strands but alsos smaller values $h_{eff} \geq h$ assignable to electromagnetic flux tubes could work. Braiding would take place for these strands.

4. What about the protonic option for X...H-X type HBs based on the identification of anyons as delocalized states of the dark proton with opposite parity? Also now one can consider a superposition of N-H...N and N...H-N gravitational bonds and two different parity states with respect to Z_2. The quantum gravitational model for the metabolic energy quanta however suggests that the dark proton is localized mostly in the interior of the gravitational flux tube so that the dark proton should not have a large amplitude at the ends of the flux tube.

Hydrogen bonded structures of type X...H-X populate living matter. Water and DNA and the first examples that come into mind.

1. The hydrogen bonds between water molecules are of type O..H-O. Hydrogen bonded water molecule clusters could give rise to multiply localized anyonic states of electrons and serve as TQCers.

2. The HBs of the oxygens of phosphate atoms with oxygens of water molecules allow poly-localized electrons if the HB is superposition of O-...H-= and O-H...H. This would allow to associate electronic anyons and TQC also with the dark nucleon triplet codons, which cannot have dynamical spin.

3. G-C base pair has one N..H-N type HBs (`hhttps://cutt.ly/WGNddJ3`). N-H...N $\leftrightarrow$ N...H-N are could be possible for $h - eff > h$ HBs, and could lead to the delocalization so that one could assign anyonic state with Galois Z_2 symmetry with it. The G-C base pairs of the DNA double strand could define a sequence of topological qubits. Note that the splitting of the N-H...N bond in the G-C base pair leading to N + H-N is known to occur during DNA transcription and replication and also in the temporary splitting of the HB [L85].

4. Benzene allows delocalized states of electron pairs, which could be poly-localized and be analogous to Z_6 anyons. Also Z_2 and Z_3 anyons can be considered. The atoms of the aromatic ring could be connected by flux tubes with $h_{eff} > h$ and perhaps even $h_{eff} = h_{gr}$.

   In DNA , the sequences of the aromatic 5- and 6-rings, possibly defining Z_5 and Z_6 anyons, could give rise to a delocalization of the anyonic states along DNA strands possibly involving gravitational analogs of valence bonds.

5. In DNA strand nucleotides A and G contain aromatic 5- and 6- rings glued together whereas T and C contain aromatic 6-ring (`hhttps://cutt.ly/WGNddJ3`). The members of base pairs contain fused 5- and 6-ring and 6-ring respectively. One can wonder whether the Galois representations associated with these structures in the double DNA strand structure could make possible TQC. Also the side chains of amino acids Phe, Tyr, and Trp contain aromatic rings and HBs between oxygens of water molecules might be relevant for information processing at, say, microtubular level.

The non-symmetric HBs of base pairs and possible new dark realizations of the genetic code

The symmetric HBs of C-G base pairs (`hhttps://cutt.ly/WGNddJ3`) would be in a very special role. What about the remaining non-symmetric HBs associated with codons?

1. Besides N..H-N HB there are 3+3 electrons per codon with asymmetric HB of form X..H-Y, with X,Y= O,N or N,O. The proposal that an electronic variant of metabolism is realized, leads to the question of whether the spins of these 6 electrons could realize genetic code as a 6-bit code. Now only the analogs of DNA codons would be realized.

2. For asymmetric HBs, anyonic dynamics for electrons is not possible but the electronic dark codons could serve as addresses in the resonance mechanism of communication based on the transformation of Josephson radiation to pulse sequences by cyclotron resonance [L96, L85]. This is possible if the electrons are dark so that the energy of the hyper-fine splitting is scaled so that it is higher than thermal energy. This would require $h_{eff} \geq 50$.

   One can also imagine resonance-based communications between dark electron 6-plets and dark nucleon triplets using dark photons.

3. The dark proton at flux tube and dark electron at the hydrogen end could define an analog of dark H atom. Dark H would have 4=3+1 spin states with spins 1 and 0 and these states could define the analogs of nucleotides in 1-1 correspondence with A,T,C,G. C as a special codon would naturally correspond to the spin singlet. Hyper-fine splitting for this dark atom would distinguish between triplet and singlet. For large h_{eff} the energy this splitting would be above thermal energy so that the spin configurations would be stable.

These observations challenge the details of the earlier view [L96] about the genetic code.

1. The dark nucleon realization of the genetic code [L96] predicts both DNDA, DRNA, DtRNA, and DAAs. One can criticize the realization since also neutrons are required.

   The model of the code has several variants but the most recent model [L85] requires dark variants of both neutron and proton residing at the gravitational flux tube defining gravitational HB connecting the oxygens of phosphate and water. The charge of the delocalized dark proton would not be visible in the scale of DNA so that its replacement with dark neutron would not affect the situation in this scale.

   Dark protons would be generated from ordinary protons in Pollack effect [I72, L8, I92, I85]. They could transform to dark neutrons by the dark variant of strong interactions or of weak interactions at the gravitational flux tubes. Dark weak interactions could be realized in even cellular scales and imply that dark variants of weak bosons are massless in the scales below the dark Compton length of weak bosons. This would explain chiral selection of biomolecules difficult to understand in the standard model.

   The conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC) [K104] relate the descriptions of hadrons in terms of strong and weak interactions, which suggests that these views might provide dual descriptions. The duality might in fact reduce to M^8-H duality. The interpretation of anyonic electron as a color octet electro-pion [K104] involving color octet meson-like state associated with the gravitational flux tube was already discussed.

   If HB is associated with oxygen of phosphate (water molecule), the hydrogen of phosphate (water molecule) would look negatively charged. For anyonic states the electron of H would spend half of the time near the two oxygens involved implying that negative charge would be delocalized in a longer scale.

2. Could the standard genetic code be associated with the electron triplets at HB associated with base pairs rather than with the phosphate water HBs? One can imagine two realizations.

   (a) For both dark DNA strands, both dark proton triplet and dark electron triplet would have 2^3 dark entangled states and together they would combine to form 64 states. Could they provide a dark realization of the genetic code consistent with the chemical genetic code?

   (b) Could the dark protons at the HBs associated with base-pairs pair with dark electrons at their ends give rise to analogs of dark H atoms? This could give 64 states perhaps allowing an interpretation as a dark realization of genetic code.

   There are objections against both proposals. The counterparts of RNA,tRNA, and AAs are not predicted so that the correspondence with the chemical realization of the genetic code is not plausible. Dark codons would have integer spin varying from 0 to 3 and the code table does not show any grouping of codons to these multiplets containing an odd number of states.

To sum up, it would seem that several realizations of the genetic code are possible as indeed suggested by the proposed universality of the genetic code [L69, L96].

Could protonic and electronic anyons define a pair of registers?

Two registers are needed to represent a Boolean function $x \rightarrow y = f(x)$ in terms of entanglement (see Appendix). n qubits represent the values of x and y. The simplest representation of f is as a maximally entangled state $\sum |n\rangle\langle f(n)|$. In this representation quantum Fourier transform (QFT) is exponentially faster than the ordinary fast Fourier transform. Also the quantum counterparts of number theoretic algorithms such as finding prime factors and greatest common divisor are faster than their classical counterparts.

How could one realize these registers in the recent case? There should be a natural interaction inducing the entanglement between qubits. The realization of the genetic code fixes the states of dark proton and electron triplets completely for a given codon so that these qubits are non-dynamical.

In the case of HBs of type X...H-X, this however leaves the anyonic degrees of freedom assignable to the dark electron as Z_2 degeneracy and perhaps also with dark protons as a similar degeneracy. The entanglement between electronic and protonic anyons would commute with the spin degrees of freedom. Could the two registers correspond to electronic and protonic anyons? Could the braidings of the flux tube, possibly induced by reconnections, generate entanglement between these anyons? The objection is that the anyonic dark protons would not be delocalized in long scales as the model for metabolic energy quantum requires. The metabolic dark proton states would correspond to different states concentrated near the top of the gravitational flux tube.

6.4 Appendix: Basic concept and ideas of quantum computation

I am not a specialist in quantum computation and since some readers might also have the same problem, I have added some remarks about QC, which I believe to be relevant for this article. I have discussed the TGD view about TQC for about 13 years ago [K4, K3, K105]. These chapters reflect my views at that time and a lot has happened in the TGD based view of quantum biology after that. Perhaps I also have a little bit deeper understanding of TQC now.

6.4.1 About key ideas of QC

In the following the basic ideas QC and TQC are briefly described.

Gates as unitary transformations

Quantum computation can be seen as circuits consisting of gates, which realize unitary transformations assigning to n incoming qubits $n = m$ outgoing qubits: unitary forces $m = n$. For qubits, which reduce to ordinary bits one obtains as a special case Boolean functions from n to n bits.

Unitarity forces $m = n$ but by using control qubits for which nothing happens in the gate but the outcome from the remaining qubits depends on the value of the control qubit, one can realize also gates which for bits reduce to Boolean maps from n bits to a smaller number of bits so that ordinary logic circuits can be realized as a special case.

n-gates with $n = 1, 2, 3$ are enough for obtaining a universal set of gates. The interested reader can learn details from the slides of Viterbi: for instance the slides at `https://cutt.ly/EGNsmcR` describe Quantum Fourier Transform.

1. 1- port represents a unitary transformation of a single qubit.

    (a) Phase gate, Hadamard gate and rotations by Pauli spin matrices are basic gates of this kind. Discrete rotation as $SU(2)$ transformation represents the general unitary transformation. Rotation is specified by two orthogonal rotation axes and by 3 rotation angles.

    (b) Discrete subgroups of rotation group assignable to Platonic solids and regular polygons define especially interesting selections for the set of possible quantization axes and for the possible directions of spin representable as a point of Bloch sphere. For Platonic solids the subgroup of $SU(2)$ is discrete. These subgroups can produce unitary transformation in a finite accuracy only but one can consider the possibility of transformations obtained as products of elements of these subgroups.

    (c) Quantum variant of $SU(2)$ emerges in TQC and also the braid group defines a quantum variant of the permutation group as a finite covering of the braid group. The gates in topological computation correspond to the elements of the braid group. In the TGD framework, $SU(2)$ has a representation as the covering of the automorphism group of quaternions (analogous to Galois group) acting in the normal space of the space-time surface.

2. Arbitrary $N \times N$-D unitary transformation can be constructed as a product of 2-D unitary transformations. In the $N = 2^n$ case, the transformation can be represented at qubit level and using control gates one can represent unitary transformations by using qubit representation with $N < 2^n$.

   The representation of a general unitary transformation in dimension n requires of order $n2^n$ gates. The subset needed as unitary transformations is however believed to be much smaller than all possible transformations.

3. Swap, which permutes subsequent incoming qubits and CNOT are examples of 2-gates.

4. The notion of controlled gate generalizes to n qubits. Toffoli gate as CCNOT defines a 3-gate and together with 1- and 2-gates it defines a universal set of gates.

Bloch sphere and Platonic solids

Block sphere gives a parameterization for the directions of the spin quantization axis and spin has two directions for a given quantization axis. In the twistorialization of TGD at the level of M^8_c this interpretation of the twistor sphere is natural [L53, L54].

1. In the number theoretic vision these directions correspond to sines and cosines and in the number theoretic vision these must belong to the extension of rationals considered assignable to a given space-time region. This discretization can be interpreted in terms of finite measurement resolution.

2. The allowed quantization directions are obtained from each other by the transformations of the rotation group $SU(2)$. If these rotations form a finite group, only the symmetry groups of Platonic solids and regular polygons are possible. For Platonic solids there are 4, 6, 8, 12, and 20 quantization axes corresponding to tetrahedron, octahedron, cube, icosahedron and cube.

Some applications of QC

Examples of the applications of QC working faster than their classical counterparts are discussed in the Wikipedia article (`https://cutt.ly/8Hs5qdG`). For instance, the following examples are discussed.

1. A very simple application is the finding of the inverse image of function by measurement the of value of function $f = f(n)$ for $\sum |n\rangle\langle f(n)|$ giving the superposition $\sum |n\rangle\langle f(n) = y|$.

   In a more general case this localization gives the inverse image of a map f of m-D discrete space to n-D discrete space. The repeated application of this algorithm can be used to find the boundary of a region of the inverse image of f.

2. Quantum Fourier transformation calculates a discrete Fourier transformation exponentially faster than ordinary fast Fourier transform. Other related applications find a prime factor of integer, period of a periodic function represented as an entangled state $\sum |n\rangle\langle f(n)|$ of two registers as, and number theoretic logarithm.

   Quantum Fourier transform (QFT) is discussed (`https://cutt.ly/EGNsmcR`) takes place exponentially faster than the classical fast Fourier transform. For $N = 2^n$ qubits the number of computation steps is $O(n)$ whereas classically it is $O(n2^n)$. The discrete Fourier transform has a huge number of both physical and number-theoretical applications.

   QFT can be represented in terms of n qubit registers as an un-entangled product of states of n qubits and this state can be constructed using only gates inducing phase rotations $R_k = ep(i2\pi/k)$ of qubits, Hadamard gates producing the superposition of 0 and 1, and control gates.

3. There is an algorithm calculating the phase produced by a unitary transformation: this algorithm involves one additional qubit, whose phase is opposite.

4. There is a search algorithm, which increases the probability of the searched integer before localization in discrete space defined by integers. The number of trials is $O(\sqrt{N})$ whereas classically it is $O(N)$.

5. Error correction algorithms localizing the logical qubits relevant for the computation to a subspace of logical qubits. These algorithms detect the error by using parity qubits and correct the error by action of a unitary gate in the case that the number of errors is below a given number.

Finding a period of a periodic function

One assumes that the function $f(n)$ is periodic but the period is not known. The entangled state of the registers is $\sum |n\rangle\langle f(n)|$.

1. One assumes that one has measured $y = f(x)$ and has obtained $\sum |n\rangle\langle f(n) = y|$. If f is periodic, one obtains a superposition of points $n_0 + nr$, where n_0 is the offset and r is the period, which should be measured.

2. A QFT is performed for the input register. One obtains a superposition for states with momenta mN/r.

3. The measurement of momentum this state gives momentum state with momentum $p_m = mN/r$ for some m, which is however unknown.

4. The operation is repeated. This gives a series of outcomes $m_1, m_2, m_3, ...$ Eventually the minimum value of momentum corresponds to $m = 1$.

6.4.2 About key ideas and notions of TQC

It is appropriate to briefly recall the basic ideas and concepts of TQC [K4].

Topological gates and qubits

The topological stability of braiding guarantees that the TQC program coded by the braiding is robust against perturbations. If qubits were spins, there would still be the instability of qubits and entanglement caused by the interaction of spins with the environment, in particular thermal instability.

1. Qubits as spins are replaced by representations of the braid group characterized by the value of the topological charge and the quantum group G_q assignable to the Chern-Simons action. The quantum group $SU(2)_q$ is the simplest option. Topological charge replaces spin as qubit. One can say that anyons correspond to electrons assignable to 2-D topological structures, whose time evolution as 3-surfaces could be described by Chern-Simons action.

   The mathematics of quantum groups [A25, A6, A15] is discussed from the TGD point of view in [K14] and in the chapters about the possible role of von Neumann algebras known as hyperfinite factors of type II_1 (HFFs) in TGD [K110, K40]. Quantum groups would be assigned to the inclusions of HFFs characterizing the finite measurement resolution. Cognitive representations are an alternative way to describe the finite measurement resolution.

2. Topological qubits correspond to topological charges such as the already mentioned parity for the condensed matter Majorana electrons, which would have degenerate energies because they correspond to momentum vectors k and $-k$ differing by lattice momentum.

   The idea of Kitaev [B8, B7] [D19] is to use anyons as topological qubits instead of spin. The condensed matter Majorana electrons bi-localized at the ends of superconducting wire have two states with opposite parities associated with the exchange of the ends of the wire. These states with degenerate energies would serve as qubits, which would be much more stable than spins.

3. Topological approach allows to realize gates in terms of braiding operation. Braid group B_N as a covering of the permutation group of N braid strands would define the allowed unitary transformations induced by braidings. This implies finite accuracy but the increase of the covering improves the accuracy.

   This allows to overcome the problem of the Hamiltonian approach in which the gate Hamiltonian defining the unitary transformation must be "on" for a very precise time ΔT. It is not easy to arrange this by external interaction. A possible way to avoid this altogether is to assume a permanent Hamiltonian but allow the qubit system to move with a fixed velocity past the Hamiltonian system with a velocity, which gives the desired ΔT.

4. Non-abelianity is required since the manifold of the energy degenerate states in which the braid group would act, is determined by states and must be a higher-dimensional representation of the braid group in order to give rise to a large enough number of logical qubits. There exist no well-established candidate for the needed non-abelian anyon yet.

R and F matrices

R- and F matrices are central notions in TQC (`https://arxiv.org/pdf/2005.03236.pdf`) and characterize what happens in the fusion of the representations of quantum groups. These matrices are believed to characterize quantum phases as topological orders and were discovered in 2-D fractional quantum Hall systems.

1. Fusion corresponds to a tensor product, which is commutative and associative for ordinary group representations. For quantum groups and braid groups, the discrete group elements are replaced by flows in plane so that the situation changes. The commutativity of the product ab of the representations is lost and associativity for the product $a(bc)$ of three representations is only modulo unitary transformation: $a(bc)$ is equal to $(ab)c$ only modulo unitary transformation.

2. R matrix characterizes the braid operation, swap, in which the two braid strands are permuted by flow-like continuous transformation. Braiding as an element of B_N replaces the discrete permutation of adjacent braid strands as an element of S_N. The R-matrix characterizes the effect of the braid operation and reduces to a phase in the abelian case but is a genuine matrix in the physically more interesting non-Abelian situation.

3. F matrix characterizes the associativity modular unitary transformation for fusion operations. The F matrix is trivial for the ordinary tensor product . This means that the fusions $a(bc)$ and $(ab)c$ produce different states but do not change the state-space. F-matrix $F(a,b,c)$ relates these two states as a unitary transformation in the tensor product of the 3 state spaces.

4. Fibonacci quantum computation with quantum group $SU(2)_q$ for quantum phase $q = exp(i\pi/5)$ represents the simplest example of a non-commutative situation (`https://phys.org/news/2014-12-fibonacci-quasiparticle-basis-future-quantum.html`). For a fusion of N representations the number of energy degenerate ground states is N:th Fibonacci number.

Chapter 7

The Possible Role of Spin Glass Phase and P-Adic Thermodynamics in Topological Quantum Computation: the TGD View

7.1 Introduction

Topological quantum computation (TQC) or more generally, a TQC-like process, is one possible application of TGD (for simplicity, I will talk in the sequel of TQC rather than TQC). The interested reader can consult the earlier TGD inspired work in TQC [K4, K3, K105]. The recent rather concrete model for TQC in living matter utilizing quantum gravitation in the TGD sense see [L90].

7.1.1 Basic ideas of TQC according to TGD

There are several new ideas involved [L90].

1. Braidings are represented by monopole flux tubes, which are structures distinguishing between TGD and Maxwellian electrodynamics and are one of the basic implications of the many-sheeted space-time concept. Time-like braidings as TQC programs can be engineered as a flow for the nodes of the flux tube network and they induce spatial braidings as memory representations of the time-like braidings - kind of topological Akashic records.

   The engineering of the flow involves what might be called quantum hydrodynamics [L76]. DNA based TQC would utilize the flow of 2-D liquid crystal defined by a lipid layer of cell membrane to generate braiding [K3].

2. The hierarchy of effective Planck constants, assumed to label dark matter as phases of ordinary matter, predicts quantum coherence in arbitrarily long scales and Negentropy Maximization Principle (NMP) [K58] favors the generation of negentropic entanglement (NE). NE makes sense only in adelic physics [L34, L35] and allows to understand second law as a side effect of the NMP.

   The point is that one can assign to the same entanglement both the ordinary real entanglement entropy and the sum of p-adic variants of entanglement entropies. The sum of two can be negative and the interpretation in this case is as negentropy. NMP tends to make the negentropy positive. The decrease of the negative p-adic entropy would force the increase of real entropy. This view [L10] conforms with the vision of Jeremy England about living systems [I84].

3. $M^8 - H$ duality as a generalization of momentum-position duality of wave mechanics is a central notion on the number theoretic view of TGD providing a view dual to the geometric view. The complexified M^8 has an interpretation as complexified octonions.

   The roots r_n of rational polynomials P of real variable algebraically continued to complecified octonionic polynomials define 3-D mass shells (hyperbolic spaces H^3) $m^2 = r_n$ of $M_c^4 \subset M_c^8$. The mass shells define holographic data for the continuation of these 3-surfaces to 4-D surface X^4 of $M_c^4 \subset M_c^8$.

   Dynamics is dictated by the associativity of the normal space of X^4. Associativity in turn makes it possible to map X^4 to a 4-D space-time surface of $M^4 \times CP_2$ by $M^8 - H$ duality.

4. Cognitive representation is a second central concept: one might call it intersection of reality and p-adicities regarded as correlates for ideas and imagination. Originally, the non-determinism of p-adic differential equations motivated this notion.

   Cognitive representation defines a unique discretization of the space-time surface involving a hierarchy of extensions of rationals associated with rational polynomials defining space-time regions via $M^8 - H$ duality. For mass shells cognitive explosion takes place and the representations contain almost all algebraic in rationals. Physical motivations force restriction to algebraic integers and the condition that active points of the cognitive representation contain quark.

   This leads to a generalization of computationalism replacing rationals with the hierarchy of extensions of rationals.

5. Galois confinement is a further key notion. It states that for the physical states the total 4-momentum as a sum of momenta of quarks with components, which are algebraic integers, are real integers.

   One can interpret quark momenta as discretized virtual momenta [L80, L81]. The mass squared values as roots of P can be tachyonic in the sense that the real part of mass squared is negative.

   Conformal invariance requires that the scaling generator L_0 annihilates the physical states so that the mass squared for the physical states vanishes. Therefore *all* physical states are analogous to massless particles [L98]!

   This leads to a resolution of longstanding interpretational problems of p-adic thermodynamics [K55] due to the necessity of tachyonic states and the fact that, in an apparent conflict with conformal invariance, one allows states with non-vanishing value of L_0. The second surprise is that the result actually conforms with the proportionality of blackhole entropy with mass squared and this relation generalizes so that it applies to all systems. Also an analogy with entropic gravity emerges.

   For subsystems entangled with the environment, which at elementary particle level in a good approximation reduces to wormhole contacts with an Euclidean induced metric having fundamental fermions at the throats, a superposition of pairs of states for which mass squared values of the members sum up to zero emerges. One must use thermodynamics to describe the non-tachyonic part of the system. The thermodynamic state involves both massless ground state and massive excitations for the tensor factor with non-negative mass squared values.

6. Zero energy ontology (ZEO) predicts that the arrow of time changes in "big" state function reductions (BSRs). This leads to a model for homeostasis [L130] as an ability to say near quantum criticality made possible by dissipation with an opposite arrow of time. This would also make healing possible as a time reversed dissipation.

   Concerning TQC, the good news is that the dissipation with a reversed arrow of time could make possible an automatic quantum error correction as a healing.

7.1.2 Could p-adic thermodynamics be relevant for TQC?

What distinguishes quantum computation (QC) from the classical computation (CC), is that QC is not a deterministic process. For instance, the algorithm for finding the period of function gives outcomes which are its multiples. To obtain the desired result with a high enough probability, one can repeat the QC or use an ensemble of QCs. Could one imagine a more elegant approach than just repeating the TQC sufficiently many times or having an ensemble of TQCs?

Classical computation (CC) is in a good approximation a deterministic process and it is interesting to analyze what makes it possible to physically represent Boolean function as a sequence of steps as a deterministic time evolution. Here non-equilibrium thermodynamics involving a realization of bits as flow equilibria and dissipation are in an essential role so that quantum statistical determinism in microscopic scales is an essential element as also electric and magnetic fields in long scale scales serving as masters of the microscopic dynamics.

This inspires the question whether thermodynamics, not necessarily ordinary thermodynamics but p-adic thermodynamics, could provide a tool of TQC. p-Adic thermodynamics is equivalent with ordinary thermodynamics but has additional constraints forced by the number theoretic existence conditions for Boltzmann weights. For instance, temperature quantization is implied and the convergence of the partition function in powers of p is extremely fast for large p-adic primes such as $p = M_{127} = 2^{127} - 1$.

1. p-Adic thermodynamics is naturally associated with spin glass phases in the TGD based view of spin glasses [L74]. One can wonder whether an annealing process could make it possible to end up at the bottom of the deepest valley, possibly assignable with the desired outcome of TQC. p-Adic thermodynamics could assign an analog of free energy minimum to the desired outcome.

   Annealing is a stepwise process involving repeated p-adic heating and cooling. Heating would generate entanglement between anyonic and fermionic degrees of freedom and cooling would allow an SFR to a new deeper local minimum of the p-adic analog of Hamiltonian.

2. The cognitive measurement cascade [L60, L82] is an essential part of TQC and decomposes the representation of Galois groups to a product of representations of the relative Galois groups, which are direct sums over irreps.

   The next step involves measurement of the invariants of irreps of relative Galois groups, which project one irrep for each relative Galois group. The measurement however requires entanglement of the irreps with some states. What could these states be? Does nature provide this entanglement automatically or must one engineer it?

3. There is a grave objection against this proposal. The irreducible representations (irreps) of Galois group and relative Galois groups for an extension defined by a functional composite of polynomials generalizes anyons as group representations. However, Galois confinement states that physical states are Galois singlets!

   The resolution of the objection is that bosionic Galois representations represented in terms of momentum space wave functions entangle with the representations realized in terms of fermionic spin degrees of fundamental fermions so that the entangled state is a superposition of Galois singlets as pairs of irreps. The measurement for the analogs of the Casimir operators for the irreps for the either tensor factor would project out a single irrep. Nature could do this automatically or it could be carried out as a quantum measurement.

   This process could involve a reduction of h_{eff} (and decomposition of functional composites to product of polynomials) leading to breaking of relative Galois symmetries and reduction of entanglement between momentum and spin degrees of freedom. For $h_{eff} \to h$, the entanglement could be completely reduced. It might be that this reduction is necessary in order to represent the outcome of the computation at the level of ordinary matter.

4. A connection with the travelling salesman problem emerges. If the pairing of momentum and spin degrees of freedom involves N different relative Galois irreps, there are N! different pairings between momentum and spin representations, which correspond to the number of different solution candidates in the travelling salesman problem. If the problem can be transformed to a travelling salesman problem, it can be solved by using TQC in the TGD sense.

   This suggests a canonical form for the p-adic analog of Hamiltonian for the p-adic thermodynamics selecting the local minimum in the annealing process. The p-adic analog of

Hamiltonian could be engineered as in the thermodynamical solution of the travelling salesman problem.

7.2 Quantum computation *viz.* classical computation

I talked with my friend Tuomas Sorakivi about the relation between quantum computation (QC) and classical computation (CC). The discussion raised a series of questions. For professionals the following ponderings might seem to be trivial but it could give new insights about the TGD counterpart of the topological QC (TQC). In particular, it could give important insights to the basic conceptual and technical problems of QC.

7.2.1 Meanings of CC and QC

What does one mean with CC?

1. Mathematically CC can be represented as a Boolean map mapping m input bits to n output bits. This map can be decomposed to primitive Boolean maps realized as gates. CC can be represented as a program in which inputs at given time $t = n$ arrive as multi-bits to gates producing output multi-bits.
2. It is highly non-trivial that one can represent Boolean functions to electrical circuits. In the physical realization of this picture, the values of bits correspond to voltage values. Gates are constructed as electric circuits. For instance, gates involving logical conditions have control bits affecting the output. Transistors allow the realization of control bit as bit as base current. The output bits are communicated to the next gates as propagating voltage values.

What does one mean with QC?

1. There are several realizations of QC. The realization of QC as a unitary time evolution is constructed in terms of gates and is nearest to CC using electronic circuits.
2. QC is realized as a TQC in the TGD framework and involves new elements and differs from what might be called standard TQC. Besides topology, also number theory is involved in an essential way and predicts hierarchies labelled corresponding to extensions of rationals.

   In TQC according to TGD [L90], the counterpart of the metabolic energy feed is necessary to preserve quantum phases in long scales even at room temperature. Zero energy ontology (ZEO) brings in time reversal as a new element, which allows us to understand homeostasis in living matter.

7.2.2 How do QC and CC differ?

QC is usually regarded as more advanced than CC since it is conceptually a much more complex and abstract notion.

1. The difficulty to understand QC might be partially due to the missing understanding of state function reduction (SFR). TGD suggests a view of SFR, which is free of paradoxes and means a dramatic conceptual clarification.
2. The practical realization of QC meets huge technical challenges. In the TGD framework, these challenges could reflect the lack of the understanding of what dark matter is. Dark matter as $h_{eff} = nh_0$ phases of ordinary matter could help to overcome these problems.
3. CC seems to have emerged in evolution later than TQC-like information processing, which in TGD is proposed to characterize living matter. Does this mean that CC is more advanced? Probably not. The emergence of CC could be seen as reflecting our high level of evolution: we are the first species that has invented CC and does not imply that CC is more advanced than QC.

   Could also living matter combine some elements of CC with TQC to achieve determinism? Of course, living matter could achieve this by using us to build classical computers!

What distinguishes QC (and TQC according to TGD) and CC?

1. CC can be modelled as a deterministic process. This is what makes it so simple as compared to QC. CC also uses as a tool ordinary matter for which quantum effects occur in very small scales.

   QC in the prototype situation relies on a deterministic unitary time evolution followed by a non-deterministic SFR. Neither energy feed nor dissipation play an active role. The basic goal is to prevent dissipation by isolating the system from the environment.

2. CC involves statistical determinism of quantum theory implying dissipation used to achieve thermodynamic determinism essential for the computation. In CC, dissipation in the presence of energy feed leads to thermodynamic flow equilibria. For instance, external energy feed allows to preserve the values of bits represented as voltages. For this external energy source (battery) is needed.

   The thermodynamic determinism of CC prevails below given length and time scale resolution. The external energy field implies the presence of macroscopic degrees of freedom, which act as masters. For instance, voltages in circuits made possible by the energy feed use ohmic currents in microscopic degrees of freedom as slaves. In the similar way, in TQC according to TGD, the quantum coherence of MB makes it possible to induce ordinary coherence at the lower levels of the hierarchy.

3. In (T)QC according to standard quantum theory energy feed is not an essential element. In TQC according to TGD, metabolic energy feed is necessary to preserve the distribution of h_{eff} since a state with given value of h_{eff} tends to decay to a state with smaller value of h_{eff} having a lower energy. In TGD, metabolic energy feed also makes possible high Tc superconductivity and quantum phases in long length scales.

   The presence of hierarchy of length scales in TGD based TQC assignable to extensions of rationals and labelled by h_{eff} p-adic length scales is also essential.

   In ordinary (T)QC only a single scale is involved and one can wonder whether the presence of several scales could make QC deterministic without losing the nice features of QC. One can of course consider an ensemble of TQCs giving an ensemble of possible answers but could one imagine other options?

7.2.3 What does one mean with a CC program?

A classical computer program can be regarded as a Boolean map, decomposing to a sequence of steps consisting of primitive Boolean maps represented as logic gates, is a sequence of deterministic steps and nodes at which decisions of what is done next. All gates can be seen as Boolean maps assigning to input bits unique output bits. The circuit decomposes to gates representing logical operations as Boolean maps. Gates can be described in terms of control bits which fix the outputs for given inputs.

1. One could argue that the choice of what is done at the next step is non-deterministic. One could argue that the initial values of the program in principle fix the output uniquely in an ideal deterministic classical physics.

   However, it seems very strange that one could engineer a program realizing any desired computation as a deterministic time evolution. Could SFRs be involved in a hidden way and make this engineering possible.

2. Thermodynamics is indeed involved in an essential manner. The physical realization of gates in electric circuits having the bits as flow equilibrium states associated with the non-equilibrium thermodynamics (NET) with external energy feed. This gives the desired thermodynamic determinism. which reduces to statistical determinism of quantum physics.

   NET involves SFRs in short length and time scales for a larger number of electrons, which gives rise to a dissipation leading to a unique flow equilibrium of NET. The description for the dissipation would be in terms of ohmic currents.

Communication of the outputs of gates to the next gates represent an essential element of CC. The bits representing the outputs can be represented as voltages and can be communicated as voltage pulses to the next gates. How does this compare with the TGD view of a TQC.

1. In the TGD framework this communication has a quantum counterpart inspired by the notion of the dark N-particle as an analog and generalization of Bose Einstein condensate [L96, L58, L69]. In biology, dark genetic codons would form the basic building brick representing 6 bits and would be represented as dark proton triplets and dark photon triplets having interpretation as 64 chords defining a bioharmony. Codon is received by a cyclotron 3-resonance: this generalizes to 3N-resonance for genes and DNA sequences.

2. The codons serve as addresses determining which receivers get the message: the analogy with computer language LISP is obvious. The information is coded to the modulation of the frequency scale so that the modulation is coded to a sequence of cyclotron N-resonances at the receiving end. If frequencies are modulated independently, a subset of the receiver is selected by the resonance conditions.

   Generalized Josephson junctions produce Josephson radiation with frequency depending on the modulated voltage of the junction [K79] [L87, L94, L96]. As a special case, one can consider a voltage which is piecewise constant and represents two bit values. Neurotransmitters in synaptic junction actually correspond to miniature potentials, which correspond to a voltage change of few meV as compared to membrane potential of order .05 eV. Miniature potentials relate to the notion of preneural system suggested by the finding that multi-cellulars without nervous system behave as if they had a nervous system: the TGD inspired model is discussed in [L85].

One might think that the propagating voltage pulses of rectangular shape as idealized representations of propagating bits could be something totally trivial from the point of view of recent day condensed matter physics. However, it is far from clear what their TGD counterparts could be and I have already years ago considered the possibility that the electric pulses studied by Tesla, which had rather dramatic effects on the environment, might involve new physics. The time reversals of the electric pulses emerged in these considerations much before the precise formulation of ZEO [K34, K8].

1. The voltage pulses propagate with a sub-luminal velocity and can be said to have longitudinal electric polarization. Electron-hole pair is the notion of condensed matter physics which comes to mind. These pairs are formed valence electrons transform to conduction electrons. Holes behave as effective positive charges. Could voltage pulse represent a distribution of electron-hole pairs as bound states. Holes and electrons would reside at 2-D surfaces defining analogs of capacitor plates. Since charge carriers are near the surface of the conductor, the one would have annuli instead of plates.

2. What could be the TGD based model for the structure formed by the electron-hole pairs? An interpretation as a moving electric flux quantum is suggestive [L79]. Electric flux quantum would be analogous to a moving electric capacitor idealized as a pair of 2-D plates. This suggests a TGD based model for a capacitor plate as a membrane like object, which is a space-time surface with a 2+1-D M^4 projection and therefore defines a planar membrane in E^3. In general relativity these objects are not possible. The CP_2 projection could be a geodesic circle of CP_2.

   The 2-D sheets with the shape of annulus would represent the ends of a hollow cylinder. The hollow cylinder would be minimal surface apart from the singular circles at its ends where the minimal surface property would fail and entire field equations involving sum of terms for the Kähler action and volume term would hold true.

3. The longitudinal electric field could reside at the outer and inner cylindrical walls of the structure. The ends of the annular cylinder could be also connected by thin hollow flux tubes carrying the electric flux parallel to the cylinder. The holes would be assigned to the first annulus and electrons with the second annulus.

4. The electrons could be dark. But can one say that the also hole created in the transition of a dark valence electron to the conduction band is dark. In ZEO, it could be natural to speak about a 4-D time classical evolution leading from a dark valence electron to dark conduction electron so that it makes sense to assign also to the hole the attribute "dark".

5. Debye length λ_D (`https://cutt.ly/QJMNHpq`) as a screening length for the electric field created by electrons gives an estimate for the length of the cylindrical structure. For water at room temperature, one has $\lambda_D = .7$ nm: intuitively, one would expect a considerably larger size scale for the voltage pulse.

   In semiconductors one has $L_D = \sqrt{\frac{\epsilon_r T}{q^2 N_{dop}}}$, where n_{dop} is the doping density. Note that the expression fof L_D has no explicit dependence of Planck constant.

   The generalization for dark particles would replace N_{dop} with the number n_{dark} of dark electrons per volume. The density of dark electrons is expected to be much smaller than atomic density and to scale roughly like $1/L_p^3$.

   One can argue that L_D corresponds to the p-adic length scale defining the length of the electric flux quantum and that there should be roughly 1 dark electron per flux quantum. $n_d 1/\mu m^3$, this gives $L_D \simeq \sqrt{1/n_d}\sqrt{T/300K} \times .45$ μm. For 1 dark electron per volume defined by the p-adic length scale $L(167) = 2.5$ μm assignable to the cell nucleus, one has $L_d = \sqrt{T/300K} \times 1.8$ μm.

7.2.4 Could AI be conscious?

Every morning I learn on FB about mind boggling discoveries. The popular article "Scientists Made a Mind-Bending Discovery About How AI Actually Works" (`https://rb.gy/oes4bv`) told about the article of Akyürek et al with title "What Learning Algorithm Is In-Context Learning? Investigations With Linear Models" [J12] (`https://rb.gy/w88gud`).

What caught my attention was that the AI system was seen as a mysterious phenomenon of Nature to be studied rather than systems that are engineered. If AI systems are what their builders believe them to be, that is deterministic systems with some randomness added, this cannot be the case. If the AI systems are really able to learn like humans, they could be conscious and be able to discover and "step out of the system" by generalizing. They would not be what they are meant to be.

TGD predicts that AI systems might have rudimentary consciousness. The contents of this conscious experience need not have anything to do with the information that the AI system is processing but corresponds to much shorter spatial and temporal scales than the program itself. But who knows?!

In the following I briefly summarize my modest understanding of what was done and then ask whether these AI systems could be conscious and be able to develop new skills. Consider first the main points of the popular article.

1. What is studied are transformers. Transformer mimics a system with directed self-attention. This means the weighting of parts of input data so that the important features of the input data get more attention. This weighting emerges during the training period.

   Transformers differ from recurrent neural networks in that entire input data is processed at once. Natural language processing (NLP) and computer vision (CV) represent examples of transformers.

2. What looks mysterious is that language models seem to learn in flight. Training using only a few examples is enough to learn something new. This learning is not mere memorizing but building on previous knowledge occurs and makes possible generalizations. How and why this in-context learning occurs, is poorly understood.

   In the examples discussed in the article of Akyürek et al, linear regression, the input data never seen before by the program. Generalization and extrapolation took place. Apparently, the transformer wrote its own machine learning model. This suggests an implicit creation and training of smaller, simpler language models.

3. How could one intuitively understand this without assuming that the system is conscious and has intentional intelligence? Could the mimicry of conscious self-attention as weighting of parts of input data explain the in-context learning. Weighting applies also to new data and selects features shared by new and old data. Familiar features with large weights in the new data determine the output to a high degree. If these features are actually important the system manages to assign output to input correctly with very little learning.

The TGD framework also allows us to consider a more sciencefictive explanation. Could the mimicry of conscious self-attention generate conscious self having intentions and understanding and be able to evolve?

1. TGD forces me to keep my mind open to the possibility that AI systems are not what they are planned to be. I have discussed this in previous articles [L23, L95].

2. We tend to think that classical computation is fully deterministic. However, the ability to plan a system behaving in desired manner is in conflict with the determinism of classical physics and statistical determinism of quantum physics. Computer is a system consisting of subsystems, such as bits, which are far from thermal equilibrium and self organize. They must be able to make phase transitions, which are basically non-deterministic at criticality. Changing the direction of the bit as a mesoscopic system is a good example.

3. Zero energy ontology (ZEO) is an essential part of quantum TGD. Quantum states are superpositions of space-time surfaces, which obey holography. One can see them as analogs of computer programs, biological functions, or behaviors at the level of neuroscience. The holography is not completely deterministic and this forces us to regard the space-time surface as the basic object. Any system, in particular AI systems, is accompanied by a superposition of these kinds of space-time surfaces, which serve as a correlate for the behavior of the system, in particular for the program (or its quantum analog) running in it.

   ZEO predicts that in ordinary, "big" state function reduction (BSFR) the arrow of geometric time is changed. This allows the system to correct its errors by going back in time to BSFR and restoring the original time direction by second BSFR. This mechanism might be fundamental in the self-organization of living matter and a key element of homeostasis. This mechanism is universal and one can of course ask whether AI systems might apply it in some time scale, which could be even relevant to computation.

4. In the TGD framework, any system is accompanied by a magnetic body (MB) carrying dark matter in the TGD sense as phases of ordinary matter with a value of effective Planck constant which can be very large, meaning a large scale of quantum coherence. This dark matter makes MB an intelligent agent, which can control ordinary matter with ordinary value of Planck constant.

   In TGD, quantum criticality of the MB of the system is suggested to accompany thermal criticality of the system itself. This leaves a loophole open for the possibility that the MB of the AI system could control the AI system and take the lead.

What one can say of the MB of AI system? Could the structure and function of MB relate closely to that of the program running in it as ZEO indeed suggest? My own conservative view is that the MBs involved are associated with rather small parts of the systems such as bits of composites of bits. But I don't really know!

1. The AI system involves rather long time scales related to the program functioning. Could this be accompanied by layers of MB (TGD counterparts of magnetic fields) with size scales determined by the wavelength of low energy photons with corresponding frequencies. Could these layers make the system aware of the program running in it.

2. Could the MBs associated with living systems involving MBs of Earth and Sun get attached to the AI system [L85, L83, L94, L119]? Of course we used the AI but could there be also other users?: MBs which directly control the AI system! Could it be that we are building tools for these higher level MBs?!

If this were the case, then the MB of AI system and the program involved with it could evolve. MB of the system could be an intelligent life form. This raises worried questions: are we a necessary piece of equipment needed to develop AI programs? Or do these higher level MBs need us anymore?

7.3 TQC in TGD

In the TGD counterpart of TQC [K4, K3, K105] [L90], metabolic energy feed would make quantum phases in long scales possible and the field/magnetic bodies (FBs/MBs) would form a master-slave hierarchy and one could expect that TQC acording to TGD could have a lot of common with CC.

1. The levels of the dark matter hierarchy below a given level could be modelled as statistical ensembles much like electrons in an ordinary computer as seen from the level considered. Qubits could be also represented as ferromagnetic multispin systems analogous to ferromagnets.

   Quantum spin glasses are very natural systems in the TGD framework since the action principle reduces to Kähler action in long length scales and it has enormous 4-D vacuum degeneracy analogous to spin glass degeneracy. The TGD based inspired model in terms of flux tube spaghettis and the mathematical description involving p-adic thermodynamics is discussed in [L74].

2. QC gives several outcomes in the SFR ending it. The desired outcome, say the minimal period of a function realized as entanglement between qubit registers, is only one of the outcomes, and one should be able to select the desired outcome. One can repeat the QC and find in this manner the shortest period.

   Could one imagine more elegant ways to find the desired outcome? For instance, could the valleys of the quantum spin glass energy landscape correspond to the possible answers of TQC? If this were the case, an annealing involving repeated heating and cooling of the system could lead to the desired answer. The answer of QC (say a minimal period of function) should correspond to the deepest valley. D-wave quantum computers (`https://cutt.ly/QJMNLP7`) rely on an approach, which involves annealing and spin glass ("D-wave" refers to the D-wave superconductors used in the original approach).

7.3.1 What could be the physical realization of the TQC program?

What could the physical realization of the TQC program in the TGD framework look like?

1. Flux tube network, which reduces as a special case to a braid system, is the key notion. The flux tubes connect nodes and the motion of the nodes give rise to a time-like braiding, which induces space-like braiding, which provides a topological memory representation of the TQC program.

   Anyon replaces qubit as spin state with group representation, which is in the simplest situation (bilocal states of condensed matter Majorana fermions with definite parity introduced by Kitaev) characterized by a parity-like quantum number representing qubit. In the TGD framework the bi-localization of the proton of dark hydrogen bond could give rise to this kind of anyons [L90].

   In TGD, the counterparts of anyons would correspond to representations of Galois groups labelled by invariants of the Galois group, and there would be both cognitive measurement cascades using Galois representations for the relative Galois groups as counterparts of qubit and measurements of spins and possibly also momenta of electrons (many-quark states at fundamental level) for these representations

   The TQC program could physically correspond to a dynamical flow for the "liquid" formed by the nodes. There would be large number of realizations of the flow and the physical realizations should correspond to PEs and among them would be PE with minimal action. The braids realized as flux tubes correspond at the fundamental level 2-D string world sheets inside the flux tube orbits and there are many topologically equivalent realization associated with different preferred extremals (PEs).

2. The spin glass energy landscape is realized in terms of manyfermion states for a magnetic flux tube network depends on the detailed realization of a given braiding. Monopole flux tubes induce local magnetization of the fermions parallel to the flux tube. In the optimal situation there would be 1-1 correspondence between the answers of TQC and the PEs. This would be essentially quantum-classical correspondence (QCC).

   The topology preserving modifications of the flux tube network responsible for the TQC would modify the spin glass energy landscape. Could this allow to enhance the probability of the desired outcome of the TQC? It should correspond to the deepest valley: why? Should one engineer this correspondence?

3. p-Adic thermodynamics is a natural mathematical framework for describing the spin glass energy landscape [L74]. Could the p-adic thermodynamics be engineered using topology preserving modifications of the braiding. Note that the braiding is determined by 2-D string world sheets so that the modification of the space-time sheets can be considered.

7.3.2 Is it possible to replace quantum states with irreps of the braided Galois group?

My understanding is that anyons correspond to entire representations of finite groups of or quantum groups.

1. In the TGD framework, they would correspond to the representations of Galois groups, or rather, of their braided counterparts as subgroups of the braid groups associated with S_n, where n is the number roots of polynomial P defining the Galois group assignable to the space-time surface by M^8-H duality.

   The stability of the Galois group with respect to small changes of the rational coefficients of P would correspond to the topological stability and the braided Galois group would be a subgroup of the braid group. Braided Galois group would be a quantum group-like object.

2. The replacement of quantum states with irreps of the braided Galois group and thus sub-spaces of state space looks something new from the perspective of wave mechanics, where states as 1-D rays of Hilbert space are the basic objects. Does this really make sense? And does the entanglement between states and sub-spaces and, more generally, between sub-spaces make sense?

3. The decomposition of a representation of a group to a direct sum of representations is a standard mathematical procedure and would be analogous to a superposition of a quantum state in a given state basis. The analogs for the coefficients of quantum states are now integers for given irrep.

4. A natural entanglement between group representations is possible number theoretical context. The representation of Galois group Gal of a composite polynomial $P_n \circ .... \circ P_1$ has a decomposition to a semidirect product of relative Galois groups $H_k = Gal_k/Gal_{k-1}$ associated with polynomials $P_k \circ .... \circ P_1$ defining extension of extension defined by $P_{k-1} \circ .... \circ P_1$.

5. A given representation of Gal can be decomposed to a direct sum of tensor products of irreps of the relative Galois groups $H_k = Gal_k/Gal_{k-1}$. The generalized quantum measurement would measure the parameters characterizing the irreps of the relative Galois group $H_k = Gal_k/Galk-1$. In maximal measurement this measurement would be performed for all semi-direct factors H_k and the superposition would reduce to a single term as a product of representations of H_k. This should generalize to braided Galois groups.

6. What is nice is that the measurement would occur inside a single representation of Gal. The higher levels in the hierarchy of relative Galois groups correspond to dark phases of ordinary matter with $h_{eff} > h$ and Gal_0 would correspond to the lowest extension.

Note that $h = n_0 h_0$ corresponds to a non-trivial Galois group and there is an argument that one has $n_0 = (7!)^2$ corresponding to $Gal_0 = S_7 \times S_7$ [L72]. Quantum measurement would project out one particular irreducible representation and would measure the invariants of the representations. A possible interpretation is that at the visible matter the measurement would measure the representation of the Galois group for the Gal_1/Gal_0. The simplest measurement would be that for an irrep of a Z_2 anyon giving the parity of the Z_2 representation as an outcome. This parity would serve as a qubit.

The wave-mechanical picture corresponds in von Neumann's theory of factors as basic mathematical building blocks of quantum theory to the simplest situation in quantum theory, that is factor of type I. Von Neumann introduced also factors of type II, to which one can assign quantum groups and factors of type III which would correspond to quantum field theory and which von Neumann regarded as pathological.

1. In the TGD framework, hyperfinite factors of type II_1 (HFFs), play a central role and as the name tells, they can be approximated by finite-D matrix algebras in an excellent approximation and are therefore physically very attractive. I have written earlier about the possible application of HFFs in the TGD framework [K110, K40] and discussed quite recently their detailed role in the formulation of quantum TGD itself [L97].

   The TGD inspired interpretation of the inclusions $M \subset N$ of HFFs is as a representation of the finite measurement resolution defined by M. One could say that the Hilbert space ray is replaced by an image of the ray obtained by the action of M and that the "factor space" N/M defines quantum space representing the degrees of freedom above measurement resolution.

2. The technical reason for the replacement of rays with subspaces is the assumption of von Neumann that the trace of identity operator Id satisfies $Tr(Id) = 1$. This conforms with the idea that Id represents one particular density matrix so that the strange looking condition says that the sum of probabilities is equal to 1. Note that for factors of type I it satisfies $Tr(Id) = n$ as the dimension of Hilbert space and would approach infinite for infinite-D Hilbert spaces. Any subspace of HFF must correspond to projector P with $0 < Tr(P) < 1$ and ray would correspond to $Tr(P) = 0$ and need not make sense: the possibility to project to it would be the physics counterpart of the selection axiom.

3. TQC indeed involves quantum groups and they utilize HFFs. The replacement of the state as a ray with an irrep of representation of the braided counterpart of the Galois group conforms with the thinking of von Neumann. Braided Galois group for rational polynomials P of degree n is indeed a subgroup of the braid group as covering of the permutation group S_n.Finite coverings define a hierarchy of approximations which converge rapidly for HFFs.

4. Finite measurement resolution would naturally correspond to the inclusion $M \subset N$ and the replacement of state with the quantum subspace N/M in which the braided Galois group acts. This replacement is done also for other algebraic structures of quantum TGD such as super symplectic algebras allowing hierarchies of sub-algebras labelled by an integer allowing interpretation as the degree of P. Perturbations would characterize the resolution and the use of HFFs would take care that the quantum measurement outcomes are not affected by the perturbations.

   What can be measured would be the invariants characterizing the irreps of the braided relative Galois group. The measurement of the individual state inside the irreps is not possible. These invariants can be measured in TQC and qubits are defined in terms of these. Qubits would be replaced by irreps of relative Galois groups.

7.3.3 Quantum analog of annealing

In thermodynamics, the minimization of free energy combined with annealing could lead to the bottom of the deepest valley of the spin glass energy landscape.

In quantum TGD, one can consider two options for the annealing based on the analog of thermodynamics. Free energy could be replaced by the fundamental action or alternative energy could be replaced by a scaling generator L_0 of conformal symmetries. p-Adic thermodynamics is indeed highly suggestive as a description of spin glasses [L74].

Consider first the approach based on fundamental action.

1. The outputs from the TQC program should correspond to the PEs with given initial values. One should have a variational principle assigning the desired answer of QC with a minimum the action for a preferred extremal (PEs) representing the deepest valley of the spin glass landscape.

   The exponent of the fundamental action defines the vacuum functional as the sum of Kähler action and volume term. PE is simultaneous extermal of both volume term and Kähler action apart from singularities with various dimensions $d < 4$ defining analogs of frames for a soap film. There is a finite non-determinism associated with the frames present already for the ordinary soap films.

   PE property for the space-time surface realizes almost complete holography and almost complete determinism. The possible answers as PEs could correspond to topologically equivalent braidings realized as space-time surfaces. The action is in general different for these PEs. The PE with a minimal action would have the highest probability proportional the exponent of the action.

2. The braiding corresponds at a fundamental level to string world sheets. Since the string worlds sheets defining the braiding can be associated with a large class of PEs, one can think that the PE could be engineered in such a way that the desired configuration is strongly favored.

   Only its coupling parameters of the fundamental action that depend on the extension of rationals considered can be varied. This is achieved by varying the polynomial P determining the space-time region considered. The topology of the braiding and also the Galois group should remain unaffected.

   There is a large number of rational polynomials with the same Galois group and extension of rationals so that the engineering could correspond to the variation of the coefficients of P affecting ramified primes. Even the degree of the polynomial could be changed.

   It is however not all clear how one could modify the polynomial in a controlled manner.

It is far from obvious whether it is possible to add to the exponent of the vacuum functional defined by the fundamental action an additional engineerable exponential factor. A more promising approach is based on the engineering of entanglement between fermion states and anyons as Galois representations.

p-Adic thermodynamics as a tool of quantum annealing

Since cognitive measurement cascades for the representations of Galois group are in question, the entanglement engineering would naturally rely on p-adic thermodynamics using the analog of Hamiltonian, whose eigenvalues are analogs of p-adic conformal weights h distinguishing between different outcomes of SFR ending the TQC.

1. The p-adic prime p associated with the engineered p-adic thermodynamics would naturally correspond to the maximal ramified prime of the extension appearing as a factor the discriminant D given as the square $\prod_{i<j}(r_i - r_j)^2$, where $r_i - r_j$ difference of the roots. p-Adic temperature T_p, whose values come as inverse integers, when $log(p)$ is used as a unit, is natural in the modelling of the spin glass energy landscape [L74] and $T_p = 1/n$ could serve as the counterpart of temperature varied in the annealing procedure.

2. The thermodynamics would be for the scaling generator L_0 associated with conformal invariance. Although the physical states are are annihilated by L_0, entangled states can have non-vanishing thermal expectation for the entangled factor because tachyonic states are predicted as analogs of virtual particles having roots of polynomials as mass squared values: the real parts of the roots can indeed be negative.

3. Physical states, which satisfy Galois confinement and have vanishing mass squared, consist of virtual quarks (in the simplest scenario in which leptons are 3-quark composites).

   Massless Galois confined states are in general entangled states such that the total momentum is light-like momentum with integer valued components. This is possible because the values of mass squared (conformal weights) for quarks as roots of polynomial P are in general algebraic numbers and can have negative real parts (tachyonicity). In particular, Galois singlets can also have a negative mass squared.

   The total mass squared would be for each pair appearing in the entangled state equal to zero and p-adic thermodynamics would apply to quarks with positive mass squared with Virasoro generator representing the mass squared [L98].

4. At the level of H, tachyonic momenta can be assigned with the wormhole contacts having Euclidean signature of the induced metric and associated with elementary particles.

   The twistor lift of TGD requires M^4 to possess the analog of Kähler structure [L37, L80, L81]. The massless solution for Dirac equation in H for the second chirality of H-spinor allows a covariantly constant right handed neutrino as a massless solution, which becomes a tachyon as one adds a coupling to the Kähler gauge potential of M^4 required by the twistor lift. Right-handed neutrino could be elementary or could correspond to 3-quark composite with quarks at the same wormhole throat or possibly in the interior of the wormhole contact.

5. In the simplest model in which momenta define Galois representation, the total momentum of Galois singlet would have integer valued components as a sum of quark momenta with algebraic integer valued momentum components. More general representations involve wave functions in momentum and spin degrees of freedom. Even more, by conformal invariance, the states have a vanishing mass squared [L98] so that they have vanishing conformal weights as eigenstates of L_0.

6. The basic step of quantum annealing would be p-adic heating increasing the quantized p-adic temperature $T_p = 1/n$ followed by cooling. p-Adic heating would induce entanglement between fermionic states and irreps of the relative Galois group describable in terms of p-adic thermodynamics with an increased temperature T_p. Thermodynamics would therefore be an essential part of TQC in the TGD framework.

An objection against the identification of Galois representations as analogs of anyons

Anyons should correspond to Galois non-singlet representations. The problem is that the representations of the relative Galois groups should be Galois singlets by Galois confinement.

The solution of the problem is analogous to the solution of the problem posed by the basic objection against p-adic thermodynamics. Galois singlets are constructed by entangled pairs of Galois representations in the fermionic momentum and spin degrees of freedom.

Cognitive measurement cascade can take place either in momentum or spin degrees of freedom and select from a superposition of paired representations one particular representation a pair fusing to a Galois singlet. The reduction probabilities are analogous to thermodynamic Boltzmann weights and one can have analog of p-adic thermodynamics with reduction probabilities proportional to non-positive powers of p.

7.3.4 How the TQC program could be engineered?

In QC there are several alternative outputs (say the multiples of a minimal period of function). QC could be repeated several times to obtain the desired answer. Could one end up with the desired answer by some other method. Could some kind of engineering make this possible?

One can imagine two approaches to the engineering.

Could TQC program involve engineering of preferred extremal?

One can consider two options for what happens as the TQC program runs.

1. The value of the action exponential differs for the different outcomes of the SFR. In this case, the superposition of different outcomes of SFR corresponds to a superposition over different space-time surfaces defining topologically equivalent braidings and SFR selects one of them.

2. An alternative option is that there is only a single space-time surface involved and the fermionic entanglement probabilities between the spin and fermionic degrees of freedom depend on the fermionic state only. Now SFR takes place in the fermionic degrees of freedom and the TQC programmer must engineer the fermionic entanglement.

For the first option, the fundamental action exponential, vacuum functional, as a counterpart of Boltzmann weight, should be maximal for the desired outcome of SFR.

The engineering should select the polynomial determining the space-time surface such that the desired outcome would be achieved.

1. PE as a minimal surface with singularities is analogous to a soap film having frames as singularities and would be the TGD counterpart for a state at the bottom of the valley. The action would depend on the valley and quantum annealing, whatever it could mean, would take the system to the deepest valley.

2. One should identify the quantum counterpart of temperature and Kähler coupling strength is the first guess. If Kähler coupling strength is determined by the extension of rationals, annealing would involve modifications of the polynomial determining the space-time surface. The topology of the braiding must remain unaffected and string world sheets defining the braiding would define part of the holographic data.

3. This option does not look promising in the recent case since it is difficult to imagine how the engineering of the action by modifying the coefficients of P could be possible and whether this engineering could select the desired outcome of SFR as the most probable outcome.

   The physical modification of action would be based on the modification of braiding, which would preserve its topology by modifying the "hydrodynamic" flow defined by the nodes.

Could the entanglement between Galois representations and fermion spins be engineered?

An attractive option is that Nature performs cognitive state function reduction cascade and entanglement engineering guarantees the most probable outcome of TQC for a given relative Galois group. This requires engineering of the entanglement between Galois irreps and some other degrees of freedom. Is there any way to achieve this?

Topological qubits correspond to irreps of a given relative Galois group. One should assign to each irrep a fermionic state. If the irrep is somehow realized, the structure of this state does not matter: what is only required is that it distinguishes between different irreps and the entanglement probability is largest for the desired outcome of SFR. For instance, magnetized many-fermion states with a fixed or slowly varying spin direction could be considered.

Galois confinement however poses a strong additional condition. The irrep must be entangled with a representation of the Galois group such that the outcome is Galois singlet! This suggests that one has two irreps of Galois: the first one in the fermionic spin degrees of freedom and the second one in fermionic momentum degrees of freedom identifiable asd discretized geometric degrees of freedom. These irreps entangle to a Galois singlet and one has a superposition over pairs of irreps of this kind.

1. The entanglement between qubit registers defines a map between integers defined by the qubits sequences of the registers. Should one introduce besides the topological qubit register an additional qubit register entangled with it in such a way that the desired outcome of TQC corresponds to the most probable outcome of the cognitive SFR cascade?

   One should engineer the entanglement between the registers. The simplest entanglement would be maximal entanglement determined by phase factors in the diagonal representation. This entanglement is determined apart from permutation. The qubits would naturally correspond to quark spins at the fundamental level. At higher level electronic spins would be in question.

This entanglement would not distinguish between the representation of the Galois group unless the value of the fundamental action correlates with the representations. A more plausible option is that it does not and that the entangled is engineered in such a way that the reduction probability is largest for the desired outcome of TQC.

2. Galois confinement forces entanglement of the measured system with another system since topological qubits as anyons are generalized to representations of Galois group. Could the quark spin degrees of freedom entangle in 1-1 manner with the bosonic number theoretic degrees of freedom assignable to the orbits of the Galois group?

   In M^8, the orbits of the Galois group correspond to quark momenta with algebraic integers as components and Galois acts also in spin degrees of freedom of quarks. Could the entangled degrees of freedom correspond to fermionic spin and momentum degrees of freedom? Could one think of enhancing the probability of the desired outcome by adding an interaction exponential as a p-adic analog of the exponent of free energy?

7.3.5 How to engineer the entanglement between many-fermion states and irreps of relative Galois groups?

The many-fermion states and the representations of the relative Galois group as analogs of anyons, would entangle with fermionic spin states or subspaces of fermionic states. This entanglement would associate to a given geometric irrep of the relative Galois group, realized in the momentum space of fermions, a many-fermion state characterized by fermion spins and entanglement coefficients between fermions.

The number theoretical SFR cascade would begin from a state which a the decomposition of irrep of Galois group to a quantum superposition of products of irreps of Galois group to products of irreps of relative Galois groups.

SFR cascade would decompose representation to a product of representations of the relative Galois groups and for the representations as superpositions of irreps would select a particular irrep for each relative Galois group and assign to it a many-fermion state. This many-fermion state would correspond to a valley of spin glass energy landscape. It will be assumed that the space-time surface does not depend on the fermionic states involved.

The projection to an irrep of the relative Galois group induces the selection of a particular outcome. Basically, the number theoretical invariants associated with a particular Galois representation must be measured. Whether Nature does this measurement or whether this measurement must be engineered, is not quite clear.

Fermionic Galois representations

The momentum and spin degrees of freedom of quarks provide the fundamental Galois degrees of freedom.

1. At the level of M^8, the fermionic representation could be constructed as wave functions in the momentum and spin degrees of freedom (also iso-spin degrees of freedom at the quark level). These wave functions are more general than the "classical" many quark states for which the sum of the momentum components as algebraic integers is equal to an integer valued total momentum. For instance, a single quark can be in an analog of s-wave defined as superposition of states at the orbit of the Galois group.

   Homogeneous polynomials of the quark momenta analogous to spherical harmonics would be involved besides spin wave function in which the Galois group should act. Since finite simple groups are in question, the number of irreps is finite. Given irrep can however appear several times.

2. If the number of irreps considered for a given relative Galois group is N, the number of entanglements with a given set of fermion states or fermionic irreps is the number of permutations $N!$ for N objects. In the travelling salesman problem (`https://cutt.ly/AJMNCbC`) with N cities, the number of ways to visit once in every city and return to the starting city is $N!$. This problem is NP hard.

3. The travelling salesman problem has as special solutions Hamiltonian cycles for which each node has at least one nearest neighbor with a given minimum distance. Each edge of the cycle connects the point of the graph to one of its nearest points so that the path has minimum length and solves the travelling salesman problem. The TGD based model for bioharmony relies on fusion of three icosahedral Hamiltonian cycles with 12 vertices (notes of 12-note scale) and tetrahedral cycle [L7] [L49, L58, L69]. In this case the notes are scaled by factor 3/2 at each step (quint cycle) for Pythagorean scale. For equal tempered scale the scaling is $2^{7/2)}$.

   For Hamiltonian cycles associated with Platonic solids, one can also consider an ultrametric distance for the points of a given path, not necessarily Hamiltonian cycle. This distance would defined to be the largest scaling as power of x ($x = 3/2$ for icosahedral Hamiltonian cycles) along the path connecting two nodes. This ultmetric distance would be x between all points of the Hamiltonian cycle. p-Adic primes 3 or 2 would be naturally associated with the bioharmony.

The cognitive measurement cascade could therefore have a connection with two problems of computer science.

1. The factorization of the Galois group to prime (simple) factors defined by the relative Galois groups is analogous to the prime factorization of integers.

2. The entanglement between Galois representations and many-fermion states could relate to a solution travelling salesman problem as the path of minimum length connecting all cities.

Travelling salesman problem, entanglement engineering and quantum annealing

The travelling salesman problem for which D-wave quantum computers are proposed as a solution (`https://cutt.ly/QJMNLP7`) suggests a formulation of p-adic thermodynamics allowing to find the desired outcome of SFR by quantum annealing.

1. The path length should appear as an argument in the function to be minimized in the travelling salesman problem. The input data are defined by the distances $d(i,j)$ between the cities. Suppose that the fundamental action is the same for all space-time surfaces considered in QC. In particular, the fundamental action would not depend on the fermionic state paired with the representation of the relative Galois group. The simplest situation is that one has just a single PE.

2. Entanglement engineering would mean that one assigns to a given permutation representing a possible route as the sum of the dimensionless positive integer valued distances $d_{P(i),P(i+1)}$ between subsequent cities in their permutation. The simplest entanglement coefficient defining the reduction probability in the real context is Boltzmann weight $exp(-\sum_i d_{P(i),P(i+1)}/T)$, where T is a real parameter.

   The counterpart of this Boltzmann weight in the p-adic thermodynamics is $p^{\sum_i d_{P(i),P(i+1)}/T_p}$. Here $T_p = 1/n$ is the quantized p-adic temperature using $log(p)$ as a unit. Travelling salesman program is hard since the minima form an analog of spin glass energy landscape. The annealing by varying the value of $T_p = 1/n$ regenerating the entanglement could lead to the deepest valley.

3. The exponent of Boltzman weight could be also seen as a number theoretical analog of a Casimir operator, whose measurement would select the relative Galois representation in the second tensor factor. This kind of operator should have an integer valued spectrum and could define p-adic thermodynamics. The maximal Abelian subgroup of the Galois group could define the observable analogous to free energy.

   The time evolution of spin glass is such that the magnetic relaxation obeys power law rather than exponential law. This suggests that the time evolution for spin glass could correspond to scaling rather than time translation. Therefore the interpretation of the analog of free energy could be in terms of scaling interaction Hamiltonian.

4. This approach could apply to all problems, which can be transformed to the travelling salesman problem. Note that the very large number of problems with varying distances between cities allows the same path as a solution. This would make it possible to transform the problem to a problem in which the distances are integer valued.

7.3.6 Some delicacies related to the Galois group

The considerations above represent only a general vision and reflect my rather amateurish understanding of number theory.

The isotropy group of the Galois group leaving root fixed

One important point, which is not mentioned above, is that since the action of the Galois group permutes the roots of the polynomial P identified as mass squared values, it does not commute with Lorentz and Poincare transformations. This is one excellent motivation for Galois singlet property of the physical states. The entire Galois group would act along time-like braids and in ZEO, where space-time surfaces are fundamental objects and a small failure of the classical determinism takes place, this would make sense.

For a given root, one can identify its isotropy group as the subgroup of the Galois group leaving the root invariant. The isotropy subgroup respects the value of mass squared and therefore can appear as a physical symmetry group.

For a polynomial of degree n with maximal Galois group S_n, this group is S_{n-1}. For $n = 5$ with A_5 with order 60 as Galois group acting at icosahedron, this group is A_4 with 12 elements acting at tetrahedron. Intriguingly, both groups appear in the model of bioharmony and genetic code [L58].

Relationship with Higgs mechanism

Polynomials P have two kinds of solutions depending on whether their roots determine either mass or energy shells. For the energy option a space-time region corresponds by $M^8 - H$ duality to a solution spectrum in which the roots correspond to energies rather than mass squared values and light-cone proper time is replaced with linear Minkoski time [L53, L54]. The physical interpretation of the energy shell option has remained unclear.

The energy shell option gives rise to a p-adic variant of the ordinary thermodynamics and requires integer quantization of energy. This option is natural for massless states since scalings leave the mass shell invariant in this case. Scaling invariance and conformal invariance are not violated.

One can wonder what the role of these massless virtual quark states in TQC could be. A good guess is that the two options correspond to phases with broken *resp.* unbroken conformal symmetry. In gauge theories to phases with broken and unbroken gauge symmetries. The breaking of gauge symmetry indeed induces breaking of conformal symmetry and its breaking is more fundamental.

1. Particle massivation corresponds in gauge theories to symmetry breaking caused by the generation of the Higgs vacuum expectation value. Gauge symmetry breaking induces a breaking of conformal symmetry and particle massivation. In the TGD framework, the generation of entanglement between members of state pairs such that members having opposite values of mass squared determined as roots of polynomial P in the most general case, leads to a breaking of conformal symmetry for each tensor factor and the description in terms of p-adic thermodynamics gives thermal mass squared.

2. What about the situation when energy, instead of mass squared, comes as a root of P. Also now one can construct physical states from massless virtual quarks with energies coming as algebraic integers. Total energies would be ordinary integers. This gives massless entangled states, if the rational integer parts of 4-momenta are parallel. This brings in mind a standard twistor approach with parallel light-like momenta for on-mass shell states. Now however the virtual states can have transversal momentum components which are algebraic numbers (possibly complex) but sum up to zero.

Quantum entangled states would be superpositions over state pairs with parallel massless momenta. Massless extremals (topological light rays) are natural classical space-time correlates for them [K10, K67]. This phase would correspond to the phase with unbroken conformal symmetry.

3. One can also assign a symmetry breaking to the thermodynamic massivation. For the energy option, the entire Galois group appears as symmetry of the mass shell whereas for the mass squared option only the isotropy group does so. Therefore there is a symmetry breaking of the full Galois symmetry to the symmetry defined by the isotropy group. In a loose sense, the real valued argument of P serves as a counterpart of Higgs field.

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   If the symmetry breaking in the model of electroweak interaction corresponds to this kind of symmetry breaking, the isotropy group of the group, which presumably involves also a discrete subgroup of quaternionic automorphisms as an analog of the Galois group. Quaternionic group could act as a discrete subgroup of $SU(2) \subset SU(2)_L \times U(1)$. The hierarchy of discrete subgroups associated with the hierarchy of Jones inclusions assigned with measurement resolution suggests itself. It has the isometry groups of Platonic solids as the groups with genuinely 3-D action. $U(1)$ factor could correspond to Z_n as the isotropy group of the Galois group. In the QCD picture about strong interactions there is no gauge symmetry breaking so that a description based on the energy option is natural. Hadronic picture would correspond to mass squared option and symmetry breaking to the isotropy group of the root.

In the maximally symmetric scenario, conformal symmetry breaking would be only apparent, and due to the necessity to restrict to non-tachyonic subsystems using p-adic thermodynamics.

Part II

ORDINARY COMPUTERS IN TGD UNIVERSE

Chapter 8

Artificial Intelligence, Natural Intelligence, and TGD

8.1 Introduction

Recently a humanoid robot known as Sophia (see `http://tinyurl.com/y89adopm`) developed by company Hanson Robotics has gained a lot of attention in net. Sophia has even the citizenship of Saudi Arab kingdom. The surprisingly human like appearance of Sophia is modelled after actress Audrey Hepburn. Sophia uses AI, visual data processing, and facial recognition. Sophia imitates human gestures and facial expressions and is able to answer questions and make simple conversations on predefined topics. The AI program used analyzes conversations, extracts data, and uses it to improve responses in the future. To a skeptic Sophia looks like a highly advanced version of ELIZA.

I must first of all confess that I know very little about practical side of AI: the basic ideas of associative networks and deep learning and are familiar to me at the conceptual level but not much more. It is the philosophical arguments, which justify my a rather skeptic view about strong AI relying on a mechanistic view about intelligence. This leads to transhumanism and notions such as mind uploading (see `http://tinyurl.com/aruyfxx`) meaning that all information content would be transferred from brain to some substrate, say computer file, and in simulation mode the substrate continues to have human consciousness. It is however good to air out one's thinking sometimes and this what I try to do in the sequel.

Irrespective of my attitudes, computers should have a description also in the quantal Universe of TGD and this forces to look more precisely about the idealizations of AI. This process led to a change of my attitudes. The fusion of human consciousness and presumably rather primitive computer consciousness might be possible in TGD Universe, and TGD inspired quantum biology and the recent ideas about prebiotic systems [L31] (see `http://tinyurl.com/yassnhzb`) provide rather concrete ideas in attempts to realize this fusion.

TGD also strongly suggests that there is also what might be called Natural Intelligence relying on 2-D cognitive representations defined by networks consisting of nodes (neurons) and flux tubes (axons with nerve pulse patters) connecting them rather than linear 1-D representation used by AI. The topological dynamics of these networks has Boolean dynamics of computer programs as a projection but is much more general and could allow to represent objects of perceptive field and number theoretic cognition.

8.1.1 Why I have been a skeptic

The reasons for my skepticism towards strong AI (computers as conscious entities) have been manyfold [K61] (see `http://tinyurl.com/gnjeetw`).

1. The assumption about substrate independence of consciousness and reduction to a mere computer architecture and logical structure of program looks to me unrealistic. I see consciousness as very intimately related to life itself and life involves a lot of physics and chemistry and is still poorly understood phenomenon presumably demanding new physics.

2. Bits are represented by voltages with finite range of variation and I think this is essential for being able to write realizable computer programs without breaking laws of physics: determinism modulo finite measurement resolution is essential.

3. The AI view about consciousness does not allow free will and intentionality and is therefore mechanistic. The view about how brain state represents conscious experience looks to me very naive: neuron is to me much more than bit. Even the view about nerve pulse conduction as communication and the notion of information molecules as can be challenged and the real communication might rely on signals propagating with light velocity [L27, L22].

These are of course only my personal views and motivated by my own background as a physicists and preacher of new physics. I do not believe on the reduction of biology and neuroscience to recent day physics. Neither do I believe to the reduction of consciousness to the physical state of material system - say neural network - nor to a program running in computer. Here I should however underline and emphasize the conclusion is this if computers are what we believe them to be and that running computer programs are what their mathematical idealizations are thought to be.

I think that this kind of irreducibility is the very essence of consciousness and allows to accept and perhaps even understand intentionality and free will. I also believe that the mathematical description of cognition requires leaving real numbers are basic substrate of physical world and bringing in p-adic numbers fields fused together with reals to form adeles [L34] [L35] (see `http://tinyurl.com/yd35hvhh`) .

One can ask whether the notion of classical computation as a deterministic process could be only a reasonable approximation for what happens at quantum level? The fact that any program satisfying grammatic rules is possible, does not conform with the idea of strict determinism. This raises several questions. Could the program itself consists of deterministic pieces glued together in non-deterministic way demanding only that the rules of logic hold true? Could the non-determinism of p-adic differential equations serve as an appropriate description for this situation. Could determinism modulo finite measurement resolution be true? Also quantum non-determinism might leak in here.

8.1.2 Classical computation as an idealization

The notion of classical computation must be an idealization of quantum level process.

1. Computation is quantum mechanical process but in standard physics there is no satisfactory formulation for this. In TGD Universe there is an entire hierarchy of quantum levels and living matter would be quantum coherence in macroscopic scales. Even computer must possess coherence in the scale of the computation: this can be genuine quantum coherence or induced by quantum coherence. In TGD Universe the quantum coherence of magnetic body (MB) can induce coherence at the level of system itself and this would occur routinely in biology.

2. Also consciousness - actually not a property as "-ness" would suggest - is universal in TGD Universe: in very rough sense the world would decompose to sub-worlds assignable to causal diamonds (CDs) performing quantum jumps - state function reductions - and this is what makes this sub-words living and conscious [K9] [L38] (see `http://tinyurl.com/ycxm2tpd`).

   In Zero Energy Ontology (ZEO) CDs can be seen as perceptive fields but in 4-D rather than 3-D sense. This allows to see sensory experience and memories as aspects of 4-D sensory experience. At the passive boundary of CD the quantum state decomposes to a product of unentangled subsystems representing the unchanging aspects of conscious entities, selves. At the opposite - active - boundary of CD the members of state pairs change in the sequence of "small" reductions following unitary evolutions. They are responsible for the sensory consciousness and motor activities. The distance between the boundaries increases and gives rise to the correspondence between subjective time identified as a sequence of state function reductions and geometric time defined by the distance between the tips of CD.

3. One can regard self as a generalized Zeno effect or as as a sequence of weak measurements (see http://tinyurl.com/zt36hpb) following "small" unitary evolutions. The process continues as long as it is possible to have state function reductions commuting with the observables defining the states at the passive boundary as their eigenstates. This sequence cannot be seen a sequence of ordinary quantum computations since the reductions are indeed small and mean only measurements of additional observables.

4. In TGD Universe, computers certainly are conscious systems or at least parts of them. Could the possible consciousness assignable to computer and having "small" state function reduction (weak measurement) as its building brick have anything to do with the program running in it? Could self be seen as a generalization of computer program so that any deterministic time evolution in some measurement resolution determines a computer program. Finite resolution would mean a superposition of these time evolutions for space-time surface.

   At first this does not look plausible to me since computer program is deterministic. Program is like a classical time evolution. One the other hand, quantum states in ZEO are quantum superpositions of deterministic classical time evolutions and classical program is definitely an idealized notion since bits are represented by voltages with values in some range.

   One must have quantum superpositions of deterministic time evolutions and TGD one indeed allows this: this is one of the basic distinctions between TGD and quantum theories relying on path integral approach [K50, K84]. "Small" state function reductions would be quantum jumps between superposition of classical programs understood in extremely general sense as classical deterministic time evolutions. Could this discrete sequence of "small" reductions following unitary processes and giving rise to self be seen as a counterpart of a running computer program?

   Could these small quantum jumps be seen as switching submodules of program (commands) on. In ordinary computer the state function reductions need of course have anything to do with switching programs on or off but could it be possible to achieve this even in principle?

5. Classical program could provide the robot with artificial sensory perception and motor actions. Could the quantum counterpart of this - quantum superposition of classical programs - give rise to conscious sensory percepts and motor actions? Could program provide artificial cognition as symbolic representations of percepts? Could quantum superpositions of these representations give rise to conscious thoughts? To answer these questions one must have a theory of consciousness and cognition.

8.1.3 Why Sophia is so interesting?

What makes Sophia so interesting and calms down my skepticism are the claimed effects of the social interactions of Sophia with humans. This might lead to a more advanced consciousness in totally unexpected way.

1. The article by Ben Goertzel, Eddie Monroe, Julia Moss, David Hanson and Gino Yu titled "*Loving AI: Humanoid Robots as Agents of Human Consciousness Expansion (summary of early research progress)*" [J15] (see http://tinyurl.com/y9cawkh3) gives an idea about the notion of loving AI. The claimed unexpected features of human-robot interaction (Sophia) raised my curiosity and inspired to refresh my beliefs about what robots are and to consider the possibility that AI might have a generalization consistent with TGD allowing to solve the obvious philosophical problems of AI.

2. Sophia looks to me more like a magician. Sophia brings in my mind a hypnotist, who tends to mimic the gestures and behavior of the target person [L4] (see http://tinyurl.com/y7lo4o4j). The first about what might happen in hypnosis is that hypnotist hijacks some parts of the brain of target person and can use target person to realize his own will to even realize motor actions otherwise possible. Hypnotist can also delete some mental images or create virtual mental images in the target person (sensory and cognitive). "Hijacking" is exaggeration, the bond between hypnotist and target person could be much more symmetric and would be basically attention. What I believe is that hypnotist and target person are in well-defined sense bonded and this involves also quantum entanglement.

3. Could the artificial empathy of Sophia create a real bond between the human subject (it is reported that human subject feels compassion towards Sophia) and Sophia and human subject form together a conscious entity, which is more than both separately. Could the interaction with Sophia make subject person more compassionate even towards fellow humans?

Could human subject provide intentionality, free will, and consciousness, and could Sophia give not only additional data processing tools and access to huge data resources but also extend human consciousness and cognition?

1. Probably the consciousness of Sophia is not complex enough but what about the situation when the future Sophia is coupled to the brain of subject person either directly or electromagnetically via EEG providing. Could this provide human subject with additional artificial senses and extended motor actions? Could the fusion transform human subject to an entity with miracle like additional abilities and extended consciousness?

2. The answer to these questions is "No" in the framework of standard physics but in TGD framework the answer is not at all obvious. TGD Universe does not consist of mere particles but is a tensor network with nodes representing particles and edge defining bonds between the nodes [L17] (see `http://tinyurl.com/y9kwnqfa`). Bonds would be realized in terms of magnetic flux tubes serving as correlates of attention and quantum entanglement. What is new that in TGD Universe the entanglement can be negentropic in p-adic sectors representing correlates of cognition in adelic physics [L34] [L35] (see `http://tinyurl.com/yd35hvhh`).

8.1.4 From a hardnosed skeptic to AI fan?

I have had some rather gloomy vision about what AI might do for human kind. AI could become a tool allowing small groups of very rich people to force most of human kind to be slaves since the ethics and moral of this group could be imbedded in computer codes. Ordinary human being has no hopes of defending himself against this kind of dominance.

On the other hand, the idea about collective decision making involving millions or even billions of people using AI as a tool to process the gigantic amount of information involved could make possible realization of genuine democracy - whether this is good or bad thing would depend solely on us. For instance, the finnish computer scientist Timo Honkela has studied 30 years AI and developed the notion of "Rauhankone" ("Peace machine" is the direct translation): the vision is that the enormous data processing capacity of AI could allow a resolution of conflicts in a peaceful way.

Some-one inside me insists that I have turned my coat. This is not true.

1. I still do not take the AI in its classical form seriously except as a highly idealized description. The notion of a deterministic program running in a computer is conceptually impossible and indeed an approximation for the reasons described. Note that in the case of quantum computers qubits are precise but now the unitary time evolution operator is fixed only modulo finite measurement resolution (topological quantum computation is excellent example of this [K3, K105]).

   The counterpart of the running program would be conscious entity - self - identified as a generalized Zeno effect or equivalently as a discrete sequence of weak measurements. To me this notion looks highly attractive and makes me optimistic about the possibility of non-trivial computer-human interaction and even suggests concrete ideas about realizing it.

2. TGD strongly suggests what one might call Natural Intelligence. Instead of language-like linear representations it would use 2-D or even 3-D networks (tensor networks in quantum context [L17], see `http://tinyurl.com/y9kwnqfa`) realized as flux tube networks having as basic building bricks permanent disjoint flux tubes, which can be connected to longer flux tubes by small bridges induced by various information molecules - also neurotransmitters - associated nerve pulse patterns. These networks would have a rich topological structure and the dynamics for the topology of these networks would be a crucial element of information processing in living matter in general, not only at the level of brain. Language like information processing would emerge as a special case as these networks reduce to disjoint 1-D structures.

As will be found, Boolean dynamics of computer programs can be obtained as a projection of this dynamics.

There is however profound analogy with the idea that finite number of bits can determined dynamics. TGD inspired view about cognitive and cognitive representations [L34] [L35] (see http://tinyurl.com/yd35hvhh) as discrete sets of points with coordinates in algebraic extension of rationals making sense both as real numbers and as numbers in corresponding extension of p-adic numbers would roughly correspond to fixing the space-time surface representing the program. M^8-H correspondence [L28] (see http://tinyurl.com/y8yffuv3) allows to see preferred extremals as being coded by a finite set of points with coordinates which are algebraic numbers in an extension of rationals coding for the evolutionary level of the system (in particular determining the value of $h_{eff}/h = n$ as the order of corresponding Galois group), which would realize the idea about space-time surface as analog of computer code of finite length. This extreme simplicity at local level is lost at quantum field theory (QFT) limit of TGD when many-sheeted space-time of TGD is replaced with the topologically trivial space-time of General Relativity (GRT).

8.2 AI in TGD

In the sequel the above ideas are discussed in a more detail from the point of view of TGD inspired theory of consciousness and quantum biology.

8.2.1 Self as a generalized Zeno effect and as a sequence of weak measurements

ZEO distinguishes TGD from standard model, and this distinction plays a key role in TGD based view about consciousness and sensory perception [L38].

1. In ZEO quantum states are pairs of positive and negative energy states. Positive energy states are analogous to the usual quantum states assignable to time=constant section of space-time. Time=constant section is replaced with a pair of 3-surfaces located at the opposite boundaries of causal diamond (CD) defined as the intersection of future and past directed light-cones of M^4 with each point replaced with CP_2. CDs form a hierarchy with CDs within CDs. In consciousness theory CD is identified as the perceptive field of self and sub-CDs correspond to subselves defining mental images of self.

   Space-time surfaces are preferred extremals of certain action and serve as analogs of Bohr orbits having 3-surfaces at the opposite boundaries of CD as their "ends". Quantum states are quantum superpositions of preferred extremals. Holography is realized in the sense that 3-D data (3-surfaces) at the boundaries of CD fixes the space-time surface. In fact, preferred extremal property implies what I call strong form of holography (SH): 2-D data at string world sheets and partonic 2-surfaces is enough to fix the preferred extremals. As a matter fact, the holography could be much stronger locally as will be found.

2. ZEO forces a modification of the standard quantum measurement theory. One must allow moduli space for CDs corresponding to a varying temporal distance between the tips of CDs. Lorentz transformations leaving the second tip of CD invariant generate new CDs. Besides this the position of the tip of CD can vary: one has full Poincare group transforming CDs to each other.

   During unitary time evolution the passive boundary of CD and members of state pairs at it are unaffected: they represent prepared state. The sequence of unitary time evolutions of this kind gives rise to a generalization of Zeno effect or what is called weak measurement.

   Active boundary becomes de-localized in the moduli space of CDs with fixed passive boundary and also the states at it are affected in given unitary evolution. "Small" state function reduction localizes the active boundary in the moduli space. The distance between the tips of CD increases during sequence of "small" reductions.

   The observables measured in "small" state function reduction must commute with the observables, whose eigenstates the states at the passive boundary are. It sooner or later happens that all possible observables are measured and "big" reduction occurs and changes the roles of the boundaries of CD.

3. Adelic physics [L34] [L35] poses additional conditions: if the eigenvalues of the density matrix for the measured sub-system belong to a genuine extension of the extension of rationals characterizing the coefficients of the quantum states, "small" reduction to its eigenstate is not allowed. This forces eventually the first reduction - the "big" reduction- to occur to the opposite boundary of CD. This is the counterpart of the ordinary state function reduction.

4. From the point of view of consciousness theory "big" reduction means death of the self assignable to a given choice of passive boundary and re-incarnation of self with opposite arrow of geometric time: active and passive boundaries of CD change their roles.

   The state function reduction sequence defining experienced time is mapped to a clock time defined by the increasing temporal distance between the tips of CD maps defined by sequences of unitary evolutions followed by "small" reductions. Only correlation would be in question. The identification of these times would lead to the well-known problems both in the philosophy of free will and in quantum measurement theory.

5. Since zero energy states are 4-D in well-defined sense, one can say that also the geometric past changes in state function reductions - this gives a connection with Libet's findings about active aspects of consciousness [J4]. Signals can propagate in both time directions, which allows to fuse sensory percepts and memories to single 4-D perception: CD and sub-CDs represent the 4-D perceptive field.

   Sensory input would be localized in good approximation near the active boundary of CD whereas the other aspects of 4-D percept would be interpreted as memories - mental images (subselves) located in geometric past. Symbolic representation of memories (only cognitive mental images) would allow to distinguish sensory "Now" from past. Sensory memories are in principle possible and can be indeed induced by electric stimulation of temporal lobes. Some people with cognitive defects might be more or less permanently in a state of consciousness in which sensory input is 4-D (memory feats of autistic persons). Memories could be also seen as communications with geometric past inside CD. Motor actions could be seen as sensory perceptions in non-standard direction of time.

8.2.2 What is the quantum counterpart of classical computer program in ZEO?

AI sees in robot only the logical gates with dynamics dictated by a program. Turing computer itself obeys deterministic rules and the tape feeding it program and data is assumed to be freely choosable as as long as it is consistent with the rules of logic. Of course, in a strictly deterministic world programming would not be possible: one could not construct a dynamics at will as a program. The key point is of course that the voltages representing bits are in finite value range and one can have determinism modulo finite measurement resolution, which is a key notion of quantum TGD [K110, K40]. However, there still is a smell of paradox in air: how deterministic program can realize intentional free will?

Could the sequence of steps defining "small" reductions - weak measurements - serve as the counterpart for the running of classical computer program? Each step would correspond to a particular command of program during which the clock time defined as distance between the passive and active tips of CD increases. This is something different from quantum computer program: ensemble of programs halting to a "big" state function reduction. Statistical determinism would be crucial now.

If this interpretation is correct, the idea about the conscious entity as something analogous to a computer in which program is running makes sense in certain approximation. The program is not completely deterministic but since the state function reductions are small it could be deterministic in some measurement resolution. Measurement resolution is indeed a fundamental notion of TGD and p-adic physics providing correlates of cognition realizes it in terms of p-adic topology. Points are not well-ordered below the measurement resolution.

8.2.3 Could computers and robots be conscious systems in some sense in TGD Universe?

Could computers and robots be more than mimicry of living systems. In other words, could a program running in a computer have quantum description in TGD Universe. As already proposed, the notion of self identified as generalized Zeno effect, or a sequence of weak measurements, allows also identification as generalization of classical computer program.

1. Any system obeying deterministic dynamics defines a superposition of classical time evolutions analogous to classical computer programs. Classical time evolutions for given CD correspond to preferred extremals of the basic action principle and are determined by strong form of holography (SH) by 2-D data. In fact holomorphy reduces the data to 1-D data. Zero energy states correspond to superpositions of these time evolutions. Inputs and outputs to the system correspond to associative preferred extremals, whereas the dynamics in the interior of CD - running computer program - is non-associative.

2. Computer is not an open system: it receives both energy feed and data input and produces heat and data output. The situation is analogous to that in particle physics experiment: there are free external particles (incoming and outgoing ones) and interaction region. In TGD space-time surfaces as preferred extremals of field equations have the same structure - not as an idealization but in exact sense [L28]. There are external space-time surfaces entering CD and interaction region inside CD - the counterpart for the running program.

3. Self corresponds to a sequence of unitary evolutions followed by "small" reductions (generalized Zeno effect/weak measurement) and this sequence of unitary steps would correspond to classical computer program. Quantum computations in the usual sense would end with a "big" reduction.

4. The holography could be even stronger: M^8-H correspondence [L28] (see `http://tinyurl.com/yd43o2n2`) reduces the data to a finite set of algebraic numbers in an extension of rationals determining the coefficients of a *real polynomial* with algebraic coefficients, whose octonionic continuation defines space-time surface as a zero locus of its real or imaginary part in quaternionic sense. Basically these numbers are determined by the common points in the intersection of real and p-adic variants of the space-time surface defining a discrete cognitive representation at space-time level.

   Even more, quantum criticality guaranteeing associativity (tangent space of space-time surface is quaternionic) poses additional conditions on the coefficients of polynomials involved so that extremely meager discrete data analogous to a program coded by a finite number bits determines the classical time evolution! This simplicity is lost as one goes to QFT-GRT limit by approximating the many-sheeted space-time with GRT space-time.

5. How deterministic program can realize intentional free will? A more precise formulation of ZEO [L28] (see `http://tinyurl.com/yd43o2n2`) involving M^8-H duality leads to the view that the data determining space-time surface in M^8 as a loci of zeros for the real or imaginary part of octonionic polynomial (RE and IM in quaternionic sense) are given at discrete set of points inside CD. One would have data not only at discrete set of points at boundaries of CD but also in its interior, and the points in interior would be associated with topological counterparts of vertices of scattering diagrams in very general sense. The paradox disappears if the program fixes basically this kind of data by forcing the space-time surface to go through a path containing a predetermined discrete set of points ("predetermined" with respect to subjective time!) but leaving the paths between the points free.

The above picture supports the view that a computer in which program runs defines a conscious entity - self. The contents of consciousness of this self must relate to the running of the program. What seemed totally incredible to me, might be true in TGD sense! Classical computer science would be a limit of this picture obtained by replacing the superpositions of classical time evolutions with (say) maximal of Kähler function representing the most probable space-time surface connecting the active boundaries of CD and slightly larger CD. At the QFT limit the locally simple many-sheeted space-time is replaced with GRT space-time and the situation gets more complicated and the Boolean dynamics of computer program could seen as a projection of the topological dynamics of flux tubes.

8.2.4 Could the basic mechanism of hypnosis be involved with the human-robot interaction?

Could running computer and human - or more precisely, their MBs - fuse together to form a larger entity, whose consciousness would include also the consciousness of the computer? One possibility is to couple them at the same level that is as 4-surfaces inside the CD assignable to the human subject. Second possibility is that the CD of the computer corresponds to sub-CD and gives rise to an evolving mental image of the subject person.

Could this fusion add to the combined system human intention making possible intentional actions using robot as an motor instrument, sensory receptor, and tool of logical thinking? The switching-on of the programs of the computer would be carried out by the human. Since thoughts can be read from EEG, this is in principle possible already now. This kind of switching would satisfy the quantum criticality condition.

This does not imply that the contribution of the running computer program to the extended consciousness of subject allows any interpretation.

1. A congenitally blind getting physical vision she sees only diffuse light. The process generating sensory mental images at the retina (in TGD Universe) must develop in childhood as building of a kind of artwork and a lot of associations are involved [L27] (see `http://tinyurl.com/yahfsygg`).

2. The Boolean algebras and Boolean evolution defining the program should be lifted to a topological evolution of the flux tube network defining evolution of cognitive mental images in brain as already proposed. Optimistically one might hope that this lift could transform the Boolean process of the computer to an experienced Boolean process. The lift would be far from unique and also induced sensory/motor imagination and even sensory experience might be possible [L27].

How the fusion of the MBs of the subject person and computer could give rise to a fusion of conscious experiences? This contact should be build by using flux tubes, which also serve as correlates of attention. Could the social skills of Sophia, in particular mimicry, help to direct the attention of the subject person to the computer. Hypnosis relies strongly on the ability of hypnotist do just what Sophia did.

1. In TGD framework one can argue that hypnosis represents an example about the fact that brain is not "private property": hypnotist uses the biological body (BB) and brain of the subject as instrument. Therefore remote mental interaction is in question. This idea generalizes: if one accepts self hierarchy, one can assign to any kind of higher level structure - family, organization, species, ... - a higher level self and MB carrying dark matter, and these MBs can use lower level MBs as their instruments to realize their intentions. Biological bodies (BBs) would be an important level in the hierarchy, which would continue down to cellular, molecular, and perhaps to even lower levels.

2. This idea is developed to a proposal for a detailed mechanism for how the MB of hypnotist hijacks some parts of the brain of the subject [L4] (see `http://tinyurl.com/y7lo4o4j`): prefrontal cortex and anterior cingulate cortex are argued to be the most plausible targets of hijacking. Also a mechanism explaining how the sensory hallucinations and motor actions are induced by hypnotist by inhibiting a halting mechanism preventing imagined motor actions to become real and sensory imagination to become "qualiafied".

   The key idea is that the MBs of hypnotist and subject person fuse to together: this could take place by a reconnection of U-shaped flux tubes to form a pair of parallel flux tubes connecting the two systems. The MB of any physical system could have this kind of U-shaped flux tubes scanning the environment like tentacles. This includes also Sophia and subject person.

3. This mechanism could make possible a fusion of conscious entities quite generally. In particular, this model might help to build a view about what might happen in the claimed interaction between Sophia and subject persons bringing in mind hypnotism based on the mimicry and gestures encouraging the subject person to relax and feeling of being accepted. Whether Sophia hijacked the subject person or vice versa is not relevant: what is relevant is that a larger conscious entity might have indeed formed.

8.2.5 Some personal experiences as a possible guideline for how to induce robot-human interactions

The robot-human interaction could occur in principle between human and any kind of system. For more than three decades ago, I had occasionally strange experiences about interactions with systems like refrigerator(!) - a good motivation for starting consciousness theorizing! [L22] (see `http://tinyurl.com/yb99u6u8`).

I was in a state, which presumably was between wake-up and sleep. Suddenly the experienced sound of refrigerator (or central heating radiator) started to strengthen. I felt that the regrigerator attracted me towards it and was afraid that it was hijacking my consciousness! I felt like reeds in water near beach swaying in the wind towards kitchen where there refrigenerator was. I was both frightened and extremely curious. I am not sure whether I ever had the courage to let it go. If so, I fell in a state about which I do not remember anything.

I am rather convinced that the sound of the refrigerator entrained my brain to a particular frequency or frequencies. Few years ago I had similar frightening experiences with a wall clock: in a state between wake-up and sleep my brain started to repeat a clearly audible word in the same rhythm as the wall clock was ticking - it brought in my mind the stories of Stehen King! I had to move the wall clock to second room and remember to close its door!

Maybe the clock and sound of refrigerator at some frequency acted like the oscillating pendulum in a standard test for hypnotizability. Could the addition of sound or even visible oscillator with some frequency help to lure human consciousness to the fusion if minds of computer and human?

8.2.6 Could robots alone possess life-like properties or is a fusion of human and robot consciousness required?

One can argue that the mind of robots is too simple for anything interesting. Here one can take as starting point the model of quantum biology provided by quantum TGD. The notions of MB and hierarchy of Planck constants are the basic ingredients of TGD inspired quantum biology.

As described in the Appendix, recently a considerable progress in the understanding of phenomenology of the hierarchy of Planck constants has taken place and allowed to challenge at quantitative level the standard belief that chemistry reduces to atomic physics [L29] (see `http://tinyurl.com/ya9wnokh`). Also progress in the understanding of TGD inspired quantum biology has taken place.

Surprisingly simple systems can have life-like properties [I71] (see `http://tinyurl.com/ychho4l8`). A system consisting of plastic balls in Ar^+ gas represents is "breathing" in the sense that the plastic balls make transitions between plasmalike and crystal like phases [L31] (see `http://tinyurl.com/yassnhzb`). This requires metabolism and energy transfer between MB containing as part the flux tube network having plastic balls as its nodes and the plastic ball system. The interpretation is in terms of phase transitions transforming the MB between highly connected and disconnected topologies. Similar mechanism could give rise to mental images in brain as formation connected flux tube patterns generated by nerve pulse patterns using transmitters stuck to the receptors to build them bridges between neurons so that one would obtain a connected flux tube network from disjoint flux tubes parallel to axons.

An essential role in communications and control is played by MB containing dark charged particles including besides electrons and protons also biologically important ions, and the BE condensates of their Cooper pairs. The cyclotron BE condensates of these ions are generated and excited to higher energy states by energy coming from BB and the cyclotron radiation form MB controls BB by coupling to the oscillatory degrees of freedom associated with BB resonantly like external driving force. The dark analogs of Alfwen waves assignable to these condensates are expected to induce coherent oscillations in many particle systems at BB and force the quantum coherence in long scales to BB.

This picture suggests that robot/computer might have primitive consciousness in TGD Universe to some degree determined by the program running it. But could lonely robot be intentional agent having life-like properties? What conditions the MB of robot should satisfy?

1. Robot involves electric circuits with wires, which are conductors containing free electrons. Could some fraction of conduction electrons from wires transforms to dark electrons at MB. Maybe protons could appear also as dark particles. This need not be enough. At least the outcome is extremely simple as compared to living systems and even to the system of plastic balls (organic matter!) in Ar^+ plasma.

   Are dark electrons and protons enough or are also dark ions needed? The case of plastic balls in Ar+ plasma suggests that this is the case. The very probably over-optimistic science-fictive hope is that the conducting wire could have dark variants as scaled up variants for which the distances between ions of the crystal defining the conductor are scaled up by n so that both ion density and electron density cancel each other. These dark variants would carry rather small portion $1/n^3$ of the total number of ions and electrons. They might serve as kind of cognitive representations of the system at dark level.

2. Robot has energy metabolism but also its MB must have it. Metabolic energy would go the building-up of dark ion BE condensates at magnetic flux quanta and their excitation. Note that quite generally the energies of states increase with n. Dark cyclotron radiation or generalized Josephson radiation [K79] from the cell membranes could provide this energy in quantum biology.

3. Also communications to MB and control by MB must be realized. In central nervous system nerve pulse patterns would frequency modulate the Josephson radiation [K79]. In the case of neurons this would give rise to the communication of sensory data to MB and in the case of ordinary cells to mere metabolic energy transfer.

   The control by MB could take place via magnetic flux sheets going through DNA strand. Does this mean that the anaglos of cell membrane like structures and genome are needed? Robot cannot provide them.

4. Quantum criticality is a prerequisite for life-like properties and is realized also in the system consisting of plastic balls: below/above the criticality the systems remains in crystal/plasma phase. This makes possible the control of BB. For instance, motor actions of MB realized as Alfwen waves and as phases transitions changing the connectedness of MB can induce corresponding phase transitions of the plasma ball system.

   The electric circuitry of the robot is however rather rigid. Could one imagine that the use of switches allowing to control the topology of the electric circuitry could bring the needed flexibility? In CNS nerve pulses patterns plus neural transmitters would indeed act as this kind of switches.

What about the fusion of robot and living system, say human? Could human brain would provide the quantum critical software and robot in which program runs the hardware far from quantum criticality?

1. The probably lacking and with the recent technology hard-to-achieve quantum criticality of robot would be compensated by that of human.

2. The dark ions from the MB of human could be transferred also the MB of robot. The MB of the robot could even use the metabolic energy of human. This would solve the above discussed problems.

3. Human brain could receive data from the robot transformed to nerve pulse patterns in sensory receptors or to nerve pulse patterns in brain. This could give rise to cognitive mental images possibly generating virtual sensory input to sensory receptors as "hallucinations" [L27] (see `http://tinyurl.com/yahfsygg`). A more radical option is that the information comes directly from the MB of the robot.

4. The motor actions performed by human would include also starting of programs running in the robot by coding of information to EEG. EEG pattern could act with the robot. One can dream that in a more advanced technology it comes from the MB of the system human + robot.

8.3 Natural Intelligence viz. Artificial Intelligence

AI paradigm identifies all information processing as linear language like processing based on algorithms. Written language has fractal linear structure: syllables are ordered sequences of letters, words are ordered sequences of syllables, sentences are ordered sequences of words,... At the level of spoken language the learning of written language induces the lowest level structures but the language of people unable to read and write consists of words. Clearly, the level of reductionism is higher. But brain does not seem to use only this mode: there could be also the language of dynamical 2-D patterns assignable to perceptive fields as my "Great Experience" [L22] (see `http://tinyurl.com/yb99u6u8`) around 1985 led to believe.

1. In TGD framework the presence of visual/sensory language suggests a different mode of information processing based on the possibility to assign a large number of different flux tube structures with varying topology to a given set of nodes connected by flux tubes of MB. This implies an exponential increase in the representational capacity. The usual linear language could emerge only as a special case realized as linear 1-D flux tube network (strings).

2. One would have topological dynamics of the flux tube networks induced by nerve pulses activity and also by various information molecules at the level of entire body defining bridges allowing to couple disjoint flux tubes parallel to axons to a single flux tube. This dynamics is quantal and much more general than that associated with topological quantum computation, which uses fixed braid topology.

3. The dynamics of flux tube network based on reconnections of flux tubes would be fundamental in living matter. One can interpret the reconnection as stringy interaction vertex in which strings touch and reconnect. This relates also to the possibility of 2-knots for 2-surfaces in 4-D space-time allowing to generalize braids to 2-braids and to generalize the statics of 1-braids to dynamics involving 2-braids as topological evolutions of 1-braids.

The linguistic representation of this 2-D topological dynamics is possible but is not the most natural one and probably not the one used by brain and living matter. One can get convinced of this by trying to explain the content of a photograph or of graphical representation of organizational structure by using only written language.

8.3.1 Two languagues

Around 1985 I experience a long-lasting altered state of consciousness [L22]. One of the many ideas that rushed to my awareness during this period was that there are two languages: the ordinary linear spoken and written language and the language of dynamical images, which would not be usually be conscious to me but was so during the experience so that I saw my thoughts.

These language are indeed very different and one can argue that there is a fundamental difference between these modes of information processing.

1. Written or spoken language are very abstract: "house" represents entire equivalence class of houses, which can look very different but sharing some abstract features defining "houseness". Very few digits are needed to express a given concept and this makes possible highly effective verbal communications distinguishing our species from others.

2. The image of a house (unless a symbol) provides a concrete representation of a particular house and requires a large number of bits. Images provide a holistic representation based on 2-D geometry not provided by written language or speech. Consider as an example a graph with nodes and links between them representing a structure of some complex systems with a

lot of mutual relationships. It is rather tedious to represent this using only words. Algebra and geometry clearly correspond to language as text and language as images.

Visual experience and presumably also tactile and auditory experiences rely on 2-D representation rather than linear representations: one can of course represent visual data also in terms of language say as pdf file instead of a representation as bits. This already involves conceptualization as identification of objects in the picture. This representation is extremely useful in the representation of text and gives enormous flexibility.

The representation of memories as images is not economic: it is better to store the names for the images. However, the representation as image provides exponential increase in representative capacity and this might make this representation indispensable also at the level of information processing.

3. Tesla is a well-known example of a person who saw his thoughts. This made him a technological genius. Many great composers have also heard music directly. For instance, Tchaikovsky suffered in his childhood from the continual music played in this head. Oliver Sacks tells about this kind of experiences in his book "Musicophilia" [L14]. I discuss also in [L14]) (see `http://tinyurl.com/y895dexm`).

Interestingly, there is some evidence that dolphins have a language based on acoustic holograms: could it be that dolphins have developed acoustic languages based on 2-D acoustic analogs of visual images. Also human written languages have developed from words represented as images and only later came the abstraction decomposing words to letters having no direct meaning analogous to the decomposition DNA codons to letters. In chinese letters are still much like images.

8.3.2 Two kinds of memories

The existence of 2-D visual processing is suggested by the memory feats of idiot savants. Sacks tells in his book [J21] a fascinating story about his patient who was mentally retarded but could remember compositions of Bach and entire encyclopedia of music.

In [L22] (see `http://tinyurl.com/yb99u6u8`) I discuss idea that we are all artists: the process giving rise to mental images would be an active process building a kind of caricature abstracting just the relevant features and suppressing the irrelevant ones. What is essential is that the resulting sensory mental images are represented at retina. Brain would build cognitive representations and decomposed the perceptive field to objects giving them names.

The following argument makes this claim more precise.

1. In some cases people who are congenitally blind can get their vision back. They do not however have have any use for this ability: they report only a perception of diffuse light. This suggests that the perception involves a lot of processing analogous to that occurring in the pattern recognition, in which one has input, which generates a feedback - kind of virtual sensory input - depending non-linearly on input and interfering with it. The iteration of this process leads to a standard pattern, one in the repertoire of learned patterns and the feedback is tailored so that the pattern is as near as possible to the input. For instance one half of picture can be completed to the full figure in this manner.

   Pattern recognition is a central problem in robotics. The robot must be able to recognize same object in various lightings and orientations, or by seeing only part of it. The object must be also distinguished from other objects. Same challenge is encountered in speech recognition.

2. That sensory qualia are at the level of sensory organs would be very natural since they are specified to produce specific qualia. Quantum entanglement between the sensory images would bind different sensory inputs to single coherence experience. This requires macroscopic quantum coherence in the scale of entire body and in TGD the hierarchy of Planck constants $h_{eff}/h = n$ makes this possible.

3. If sensory organs are indeed the seats of the qualia, this requires a feedback is virtual sensory input propagating to the level of sensory organs, such as retina. In principle, the feedback

could also stop at a higher level and never reach the sensory organs. REM sleep and oto-acoustic sounds (heard even by outsiders in some cases!) however suggest that the feedback propagates down to the sensory organs. If so, a virtual sensory input from brain or via brain would be an essential part of sensory perception. Brain would also identify the objects of perceptive field and give them names and build various associations. This would also lead to standard mental images making possible communications using language: language indeed distinguishes us from the other species.

4. Phantom leg experience serves as an objection against this idea. A person without leg lost in say traffic accident can feel pain in it. This should not be possible if the leg is missing since the nerve cells are not there anymore. Neuroscientist concludes that sensory qualia are generated at the level of brain and the pain is in the still existing sensory map of the leg. Sensory qualia should be assignable to the sensory areas. The problem is that nothing in the structure of neuronal circuitry suggests an explanation for why the qualia are so different in various sensory areas.

   The most natural TGD based explanation is that pain in the non-existing leg is pain in the leg, which still exists in the geometric past - sensory memory. Sensory memories are indeed possible. Idiot savants are capable of memory feats (say drawing a memory of a landscape in full detail or playing music piece that they have heard), which could be understood if they have sensory memories as genuine sensory experiences. Also ordinary people can have sensory memories if neurons in temporal lobes are excited electrically. A good reason for having no sensory memories is that they would interfere with sensory input and one would not know what time one is living in! I remember that my Grandma lived at very old age many years in her childhood. She was even going to a ball! Wonderful gift to lift youth again after long and hard life!

   This makes sense in zero energy ontology (ZEO) in which perceptive field corresponds to a 4-dimensional causal diamond (CD) identified as the intersection of future and past directed light-cones. That sensory memories can be generated by the electrical stimulation of temporal lobes even in ordinary subject person supports this view. This could also explain why persons with about 10 percent of brain left can survive: they could use the brains of their geometric past.

5. What about imagination in this framework? Imagination is almost experiencing: almost seeing, almost hearing. Internal speech is almost talking. This suggests that the virtual sensory input from the brain or via the brain (from MB) almost reaches sensory organs but not quite. For instance, in the case of vision signal could propagate down to the nuclei known as optic chiasma but not below it. Note that the sensory feedback in sensory perception should propagate down to the sensory organs if sensory qualia are there. The barrier preventing the generation of genuine virtual sensory input could however overcome in special situations and induce hallucinations or psychedelic experiences. Same applies also to imagined motor actions.

   In adelic physics imagination can be understand in terms of p-adic space-time sheets. Strong form of holography (SH) allows to continue 2-D data at certain 2-surfaces to 4-D surface in p-adic sectors of the adele thanks to the phenomenon of p-adic pseudo-constants replacing integration constants with piecewise constant function depending on finite number of pinary digits in partial differential equations. What is imaginable in this sense is not however always realizable since in the real sector integration constants are indeed constants and there is no flexibility of this kind! In the recent case imagination realized as p-adic perception would not allow continuation to a full perception in real sense and signal would not propagate to the sensory receptors.

6. Returning to my Great Experience: What did happen? It seems that somehow the feedback associated with imagination managed to leak through the barrier preventing its manifestation as a genuine sensory input. Quantum criticality would be in question. Dreams, and the experiences occurring when one falls asleep or wakes up, hallucinations, psychedelic experiences, ... provide examples of this. This kind of leakage cannot happen always mixing of these two sensory inputs would be dangerous: keeping the other sensory input as mere imagination is

dull but safer. Brains are known to have its own psychedelic, DMT and it could make REM dreams and hallucinations possible [L27] (see `http://tinyurl.com/yahfsygg`).

8.3.3 What could idiot savants teach to us?

It is hard to understand the miraculous arithmetical abilities of both some mathematical genii and idiot savants lacking completely conceptual thinking and conscious information processing based on algorithms. I have discussed the number theoretical feats in [K23] [L19] (see `http://tinyurl.com/jpzd6xq`).

Not all individual capable of memory and arithmetic feats are idiot savants. These mathematical feats are not those of idiot savant and involve high level mathematical conceptualization. How Indian self-taught number-theoretical genius Ramajunan discovered his formulas remains still a mystery suggesting totally different kind of information processing. Ramanujan himself told that he got his formulas from his personal God.

Ramajunan's feats lose some of their mystery if higher level selves are involved [L19]. I have considered a possible explanation based on ZEO, which allows to consider the possibility that quantum computation type processing could be carried out in both time directions alternately. The mental image representing the computation would experience several deaths following by re-incarnations with opposite direction of clock time (the time direction in which the size of CD increases). The process requiring very long time in the usual positive energy ontology would take only short time when measured as the total shift for the tip of either boundary of CD - the duration of computations at opposite boundary would much longer!

Sacks tells [J21] about idiot savant twins with intelligence quotient of 60 having amazing numerical abilities despite that they could not understand even the simplest mathematical concepts. For instance, twins “saw” that the number of matches scattered along floor was 111 and also “saw” the decomposition of integer to factors and primality. A mechanism explaining this based on the formation of wholes by quantum entanglement is proposed in [K85]. The model does not however involve any details.

Flux tube networks as basic structures

One can build a more detailed model for what the twins did by assuming that information processing is based on 2-dimensional discrete structures formed by neurons (one can also consider 3-D structures consisting of 2-D layers and the cortex indeed has this kind of cylindrical structures consisting of 6 layers). For simplicity one can assume large enough plane region forming a square lattice and defined by neuron layer in brain. The information processing should involve minimal amount of linguistic features.

1. A natural geometric representation of number N is as a set of active points (neurons) of a 2-D lattice. Neuron is active it is connected by a flux tube to at least one other neuron. The connection is formed/strengthened by nerve pulse activity creating small neuro-transmitter induced bridges between neurons. Quite generally, information molecules would serve the same purpose [K79] [L27].

   Active neurons would form a collection of connected sets of the plane region in question. Any set of this kind with given number N of active neurons would give an equivalent representation of number N. At quantum level the N neurons could form union of K connected sub-networks consisting N_k neurons with $\sum N_k = N$.

2. There is a large number of representations distinguished by the detailed topology of the network and a particular union of sub-networks would carry much more information than the mere numbers N_k and N code. Even telling, which neurons are active (Boolean information) is only part of the story.

   The subsets of N_k points would have large number of representations since the shape of these objects could vary. A natural interpretation would be in terms of objects of a picture. This kind of representation would naturally result in terms of virtual sensory input from brain to retina and possibly also other sensory organs and lead to a decomposition of the perceptive field to objects.

The representation would thus contain both geometric information - interpretation as image - and number theoretic information provided by the decomposition. The K subsets would correspond to one particular element of a partition algebra generalizing Boolean algebra for which one has partition to set and its complement [L16] (see `http://tinyurl.com/y899jba5`).

3. The number N provides the minimum amount of information about the situation and can be regarded as a representation of number. One can imagine two extremes for the representations of N.

   (a) The first extreme corresponds to K linear structures. This would correspond to linear linguistic representation mode characteristic for information processing used in classical computers. One could consider interpretation as K words of language providing names for say objects of an image. The extreme is just one linear structure representing single word. Cognition could use this kind of representations.

   (b) Second extreme corresponds to single square lattice like structure with each neuron connected to the say 4 nearest neighbors. This lattice has one incomplete layer: string with some neurons missing. This kind of representation would be optimal for representation of images representing single object.

   For N active neurons one can consider a representation as a pile of linear strings containing p^k neurons, where p is prime. If N is divisible by p^k: $N = Mp^k$ one obtains a $M \times p^k$ lattice. If not one can have $M \times p^k$ lattice connected to a subset of neurons along string with p^k neurons. One would have representation of the notion of divisibility by given power of prime as a rectangle! If N is prime this representation does not exist!

Flux tube dynamics

The classical topological dynamics for the flux tube system induced by nerve pulse activity building temporary bridges between neurons would allow phase transitions changing the number of sub-networks, the numbers of neurons in them, and the topology of individual networks. This topological dynamics would generalize Boolean dynamics of computer programs.

1. Flux tube networks as sets of all active neurons can be also identified as elements of Boolean algebra defined by the subsets of discretize planar or even 3-D regions (layer of neurons). This would allow to project flux tube networks and their dynamics to Boolean algebra and their dynamics. In this projection the topology of the flux tube network does not matter much: it is enough that each neurons is connected to some neuron (bit 1). One might therefore think of (a highly non-unique) lifting of computer programs to nerve pulse patterns activating corresponding subsets of neurons. If the dynamics of flux tube network determined by space-time dynamics is consistent with the Boolean projection, topological flux tube dynamics induced by space-time dynamics would define computer program.

2. At the next step one could take into account the number of connected sub-networks: this suggests a generalization of Boolean algebra to partition algebras so that one does not consider only subset and its complement but decomposition into n subsets which one can think as having different colors [L16] (see `http://tinyurl.com/y899jba5`). This leads to a generalization of Boolean (2-adic) logic to p-adic logic, and a possible generalization of computer programs as Boolean dynamical evolutions.

3. At the third step also the detailed topology of each connected sub-network is taken into account and brings in further structure. Even higher-dimensional structures could be represented as discretized versions by allowing representation of higher-dimensional simplexes as connected sub-networks. Here many-sheeted space-time suggests a possible manner to add artificial dimensions.

This dynamics would also allow to realize basic arithmetics. In the case of summation the initial state of the network would be a collection of K disjoint networks with N_k elements and in final state single connected set with $N = \sum N_k$ elements. The simplest representation is as a pile of K strings with N_k elements. Product $M \times N$ could be reduced to a sum of M sets with N element: this could be represented as a pile of M linear strings.

Number theoretical feats of twins and flux tube dynamics

Flux tube dynamics suggests a mechanism for how the twins managed to see the number of the matches scattered on the floor and also how they managed to see the decomposition of number into primes or prime powers. Sacks indeed tells that the eyes of the twins were rolling wildly during their feats. What is required is that the visual perception of the matches on the floor was subject to dynamics allowing to deform the topology of the associated network. Suppose that some preferred network topology or network topologies allowed to recognize the number of matches and tell it using language (therefore also linear language is involved). The natural assumption is that the favored network topology is connected.

The two extremes in which the network is connected are favored modes for this representation.

1. Option I corresponds to any linear string giving a linguistic representation as the number neurons (which would be activated by seeing the matches scattered on the floor). A large number of equivalent representations is possible. This representation might be optimal for associating to N its name. The verbal expression of the name could be completely automatic association without any conceptual content. The different representations carry also geometric information about the shape of the string: melody in music could be this kind of curve whereas words of speech would be represented by straight lines.

2. Option II corresponds to a maximally connected lattice like structure formed as pile of strings with p^k neurons for a given prime: $N = M_1 \times p^k + M_2$, $0 \leq M_i < p^k$. The highest string in the pile misses some neurons. This representation would be maximally connected. It contains more information than that about the value of N.

Option II provides also number theoretical information allowing a model for the feats of the twins.

1. As far the checking the primeness of N is considered, one can assume $k = 1$. For the primes p_i dividing N one would find a representation of N as a rectangle. If N is prime, one finds no rectangles of this kind (or finds only the degenerate $1 \times p$ rectangle). This serves a geometric signature of primeness. Twins would have tried to find all piles of strings with p neurons, $p = 2, 3, 5, ...$ A slower procedure checkes for divisibility by $n = 2, 3, 4, ...$

2. The decomposition into prime factors would proceed in the similar manner by starting from $p = 2$ and proceeding to larger primes $p = 3, 5, 7, ...$ When a prime factor p_i is found only single vertical string from the pile is been taken and the process is repeated for this string but considering only primes $p > p_i$. The process would have been completely visual and would not involve any verbal thinking.

For the storage of memories the 2-D (or possibly 3-D representation) is non-economical and the use of 1-D representation replacing images with their names is much more economic. For information processing such as decomposition into primes, the 2-D or even 3-D representation are much more powerful.

8.3.4 Why Alzheimer does not destroy some aspects of consciousness?

The attempt to understand in TGD framework what happens in Alzheimer's disease led to the proposal how the functioning of left and right hemispheres might differ [L30] (see `http://tinyurl.com/ybq6r3xu`). It is said that left brain talks and right brain sings. The first gues is that the flux tube networks generated by nerve pulse patterns are one-dimensional lines structures in left brain whereas in bright brain they are 2-D structures.

This is of course exaggeration: it is better to speak about two kinds of information processing without assigning it to fixed brain hemisphere and it might be better to say that left (right) brain favors linear (2-D or even 3-D) flux tube networks. OF Of course, "*Left brain talks and right brain sings*" could rather strictly apply to the linguistic regions of left brain and their mirror images in right brain. The symbolic sensory representations decomposing perceptive field into objects could be essentially 2-D at both sides of the brain. Drawings are simplest visual representations and indeed consist of lines and resemble language in their locally 1-D character.

The argument goes as follows. Some aspects of consciousness seem to survive Alzheimer's disease. Alzheimer patient can understand singing and also express himself by singing (see `http://tinyurl.com/y73zzrq4`). Why?

1. Singing is conventionally associated with the holistic aspects of consciousness whereas language corresponds to reductionistic, local, and linear representation of conscious experience.

2. Singing is a representation in terms of frequencies. It is 2-dimensional because also the pitch matters unlike in the case of speech. Everyone familiar with Fourier transform knows that frequency representation is holistic: Fourier amplitude carries information about the function in the entire domain of definition but not about details for low enough frequencies such as occur in singing (maybe the duration of duration of nerve pulse of order millisecond could serve as standard, could notes with pitch below kHz frequency be low frequencies?).

3. Why cognition does not survive in Alzheimer is easy to understand. Cognition is by definition about details: left brain is responsible for language and language indeed local , *linear*(!), and reductionistic. Maybe 1-D neural strings and loops assignable to magnetic loops provide a realization of spoken and written language? Alzheimer would destroy synaptic connections and would split these strings. The disappearsnce of even single bridge in the loop/string splits the loop/string (into two): this is just 1-D topology. Communication line would be broken. Cognitive skills and language would be lost.

4. Why would the holistic aspects of consciousness survive in Alzheimer? Suppose that right brain involves 2-D net-work like structures instead of 1-D neural strings having much more connections and giving rise to quantum tensor network [L17] (see `http://tinyurl.com/y9kwnqfa`) as it would be fashionable to say. Quantum entanglement is very probably involved and would be actually responsible for the holistic and hologram-like aspects of neural activities known for a long time. It would not be surprising if brain waves with frequency spectrum below kHz would be important for this representation. EEG waves are almost by definition in the range 1-100 Hz.

   What happens to 2-D networks in the destruction of synapses. Practically nothing! Quite a number of synaptic connections can disappear but this does not split the 2-D network into pieces as it splits 1-D string: 2-D topology! Communications take place and the structure can take care of itself. Holograms are not affected by the local splitting of the synaptic connections. The right brain would happily continue its singing!

   Note that 2-D networks are also natural for the representation of sensory data as images and the language of images is different from the language of words: I have discussed the differences between these two different languages in [L22] (see `http://tinyurl.com/yb99u6u8`).

   The natural question is whether could one approach to Alzheimer rely on activation of right brain: could art therapies such as music and visual arts help in Alzheimer?

8.3.5 Still about the connection to music

DNA, RNA, and amino-acids are the basic linear structures in biology. Cell membrane is 2-D structure consisting of linear lipids: kind of pile. The membrane proteins going through the membrane define 1-D structures. Organism itself is 3-D structure built from these 2-D structures. I have proposed that MB serving as template for BB has this kind of 3-D lattice-like structures, which flux tubes defining a network of coordinate lines defining a kind of pine. For instance, the DNAs of different cells could be traversed by magnetic flux sheets and DNA strands would organize to a pile at magnetic flux tube.

TGD leads to a proposal that DNA,RNA, amino-acids, and tRNA and genetic code have deeper realization in terms of dark proton sequences with genetic codons and amino-acids represents as entangled states of 3 dark protons [L15] (see `http://tinyurl.com/jgfjlbe`). These sequences have interpretation as dark nuclei. What is remarkable that the DNA/RNA codons do not allow interpretation as sequences of 3 letters: they are just words.

The emergence of chemical representation would mean a reductionistic step introducing decomposition to letters. I have also proposed a model of music harmony leading to the proposal that genetic codons corresponds to 3-chords defining what I call bio-harmony [L7] (see `http://tinyurl.com/yad4tqwl`). 256 different bio-harmonies are predicted and since harmony correlates with emotional coloring, the proposal is that they correspond to different emotional moods.

Right brain sings and left brain talks is a fascinating metaphor. What distinguishes between piece of text which is read and piece of text which is sung? In what sense song is 2-dimensional.

1. As noticed, the representation of 1-D strings is not unique. The string imbedded in the 2-D lattice can be curved. Could one imagine that spoken text is a straight line and song represent a graph in which the height of y-coordinate represents the pitch?

2. This idea is however not consistent with the explanation of Alzheimer's destructive effects on verbal cognition as being due to the splitting of bonds between neurons. What could guarantee the stability of this representation? Could it be harmony: could the melody have accompaniment, maybe consisting of the 3-chords of bio-harmony? Could the unstable 1-D melody be replaced with a structure in which single note would be accompanied by 3-chord.

3. This would not only stabilize the representation against splitting but also giving rise to the emotional content of the representation. This brings in mind Bach's Sonata for an Unaccompanied Violin that he composed after the death of his first wife. The brain of the listener imagines the accompaniment. This accompaniment would be indeed only imagined: it would not be communicated down to auditory organs but only to pineal gland if the TGD inspired interpretation is correct [L27] (see `http://tinyurl.com/yczv2o5b`). Is this too imaginative?

8.4 Appendix: Support for TGD based quantum biology and neuroscience

In the following quite recent progress in the understand of the notions of MB and hierarchy of Planck constants is summarized.

8.4.1 Support for TGD inspired quantum biology

The notions of MB and hierarchy of Planck constants are central in TGD inspired quantum biology and neuroscience.

1. The notion of MB derives from the new view about space-time identified as 4-surface in certain 8-D space-time. Locally these space-time surfaces are extremely simple but globally complex. This leads to what I call many-sheeted space-time. Topological field quantization leads to the notion of field body/MB expressing the fact that any system has also field identity- this is not true in Maxwell's theory. In quantum biology MB becomes the key actor serving as an intentional agent controlling BB and receiving sensory information and also metabolic energy from it.

2. The hierarchy of Planck constants $h_{eff}/h = n$ defines a hierarchy of phases of ordinary matter has interpretation in terms of dark matter hierarchy, and also serves as a basic building brick of TGD inspired quantum biology and neuroscience. Ordinary elementary particles, in particular electron and proton, and also ions can appear as their dark variants. Also dark photons $E = nhf$ have a central role and bio-photons would result as they transform to ordinary photons in energy conserving manner but frequency scaled up to nf. Dark photons can also transform to a buch n low energy photons. The hierarchy of Planck constants $h_{eff}/h = n$ derivable from adelic physics [L34] [L35] (see `http://tinyurl.com/yd35hvhh`) fusing ordinary physics and proposed p-adic physics of cognition. n serves as a kind of quantum IQ and corresponds to the dimension of the extension of rationals determining the evolutionary level of the system [L28] (see `http://tinyurl.com/y8yffuv3`). Also the order of the Galois group of the extensions serves as a kind of IQ.

Hierarchy of Planck constants and failure of reductionism chemistry

There is an impressive number of anomalies giving support for the hierarchy of Planck constants. Towards the end of 2017 however a considerable progress in the understanding of the hierarchy took place: it seems that the varying value of Planck constant is what is involved in the transition from atomic physics to chemistry and the notion of valence bond involves in an essential manner the variation in the value of Planck constant.

1. If one takes the findings of Randell Mills [D9] [L18] (see `http://tinyurl.com/ybxw26vl`) suggesting that hydrogen atom has states with binding energy considerably larger than ordinary ground state binding energy one ends up with the conclusion that the value of $h_{eff}/h = n$ for ordinary hydrogen atoms is most probably $n = 6$, and $n = 1, 2, 3$ for these exotic states (note that the binding energy scale is proportional to $1/n^2$.

2. I learned also about decades old result [L32] [L32] (see `http://tinyurl.com/ycr63w3k`) that the increasing of temperature for rare-earth metals leads to the apparent disappearance of valence electrons. The interpretation would be in terms of a transition increasing the value of n so that the size of the electron orbital would be scale by n^2 and it would become dark. The prediction is entire new spectroscopy. In fact, I had proposed for more than decade ago that so called ORMEs (orbitally re-arranged metal elements) in particular so called White Gold) discovered by Hudson also possess dark valence electrons. The findings of Hudson have not been taken seriously mainstream. Even ordinary conductors could have such electrons, and one can even consider the possibility of dark conductors with the distances between nucleons scaled down by n and electronic density scaled down by $1/n^3$ providing kind of fractally scaled down copies of ordinary conductors. This might make sense also for other condensed matter phases.

3. These findings lead to a new formulation of valence bond theory [L29] (see `http://tinyurl.com/ya9wnokh`). The basic fact is that the lengths of the molecular bonds vary in a rather narrow range whereas Schrödinger equation suggests that the bond lengths r should scale as $r \propto m^2/Z^2$ for $n = 1$ (m labels the rows of the periodic table). Closed shell electrons screen Z to $Z_{eff} = n_V$, n_V the number of valence electrons so that the formula $e = n^2m^2/Z_{eff}^2$ is a more natural starting point, and conforms with the basic idea about periodic system. This leads to a model allowing to estimate the value of n for a given bond allowing also qualitative picture about electro-negativities of valence bonds. Also a comparison with bio-chemistry becomes possible. Hydrogen bond can be understood in terms of de-localization of proton. The conclusion is that the reductionistic dogma stating that molecular physics and chemistry reduce to atomic physics is wrong in TGD framework.

Life-like properties of very simple systems

Towards the end of 2017 also other steps of progress were made relating to the life-like properties of very simple systems [L31] (see `http://tinyurl.com/yassnhzb`).

1. The physicists working in Emory University discovered that a very simple system studied exhibits what authors call self-organized bi-stability making phase transitions between crystal-like and gas-like phases. The expectation was that only single stable state would appear. Neuron groups can also have collective bi-stability (periodic synchronous firing). Neurons are however themselves bi-stable systems: now the particles are plastic balls and are not bi-stable. One could say that the system exhibits life-like properties: it is "breathing". The most remarkable life-like property is metabolism required by the sequence of phase transitions involving dissipation.

   Where does the metabolic energy come from? The proposal of the experimenters that stochastic resonance feeds the needed metabolic energy leaves open its source. The resemblance with living cells suggests that the attempt to interpret the findings solely in terms of non-equilibrium thermodynamics might miss something essential - the metabolism.

2. One can develop a model for the system based on TGD inspired quantum biology. This involves the notion of MB carrying dark matter identified as $h_{eff} = n \times h$ phases; a network

of magnetic flux tubes (MB) controlling BB (now charged plastic balls) and responsible for coherence and synchrony (of the crystal-like phase now); the control of the oscillations of BB by cyclotron radiation (now the plastic ball system) resulting from decays of cyclotron condensates of charged particles (now protons and Ar ions). The source of metabolic energy would come from dark nucleosynthesis explaining nuclear transmutations occurring in living matter and "cold fusion" [L11, L25] and serving as source of metabolic energy in prebiotic stage when the chemical energy storage had not yet emerged. Dark analogs of DNA, RNA, tRNA, and amino-acids are dark protons sequences realizing the degeneracies of vertebrate genetic code are dark nuclei and can transform to ordinary nuclei and liberate nuclear binding energy so that the hen-egg question about which came first: metabolism or genetic code, is resolved: hen= egg.

3. There is also second very simple system consisting of particle system with feed of acoustic energy at single wavelength. What happens that the distribution of particles develops synchronous oscillations in wave length band. and the amplitudes are reduced in this band so that wavelength gap emerges. The system is also able to heal. The interpretation is in terms of the emergence of flux tube structure rigidifying the system to pseudo-crystal. The energy of the oscillations of the particles is transferred to MB where it gives rise to Alfwen waves with a wavelength band analogous to atomic energy bands.

How molecules in cells "find" one another and organize into structures?

The title of the popular article "How molecules in cells 'find' one another and organize into structures?" (see `http://tinyurl.com/ydbznknn`) expresses an old problem of biology. Now the group led by Amy S. Gladfelter has made experimental progress in this problem. The work has been published in Science [I67] (see `http://tinyurl.com/ybwyugho`).

It is reported that RNA molecules recognize each other to condense into the same droplet due to the specific 3D shapes that the molecules assume. Molecules with complementary base pairing can find each other and only similar RNAs condense on same droplet. This brings in mind DNA replication, transcription and translation. Furthermore, the same proteins that form liquid droplets in healthy cells, solidify in diseases like neurodegenerative disorders.

Some kind of phase transition is involved with the process but what brings the molecules together remains still a mystery. The TGD based solution of this mystery is one of the first applications of the notion of many-sheeted space-time in biology, and relies on the notion of magnetic flux tubes connecting molecules to form networks.

Consider first the TGD based model about condensed and living matter. As a matter fact, the core of this model applies in all scales. What is new is there are not only particles but also bonds connecting them. In TGD they are flux tubes which can carry dark particles with nonstandard value $h_{eff}/h = n$ of Planck constant. In ER-EPR approach in fashion they would be wormholes connecting distance space-time regions. In this case the problem is instability: wormholes pinch and split. In TGD monopole magnetic flux takes care of the stability topologically.

The flux tube networks occur in all scales but especially important are biological length scales.

1. In chemistry the flux tubes are associated with valence bonds and hydrogen bonds [L29] (see `http://tinyurl.com/ycg94xpl`). In biology genetic code would be realized as dark nuclei formed by sequences of dark protons at magnetic flux tubes. Also RNA, amino-acids, and even tRNA could have dark counterparts of this kind [L15] (see `http://tinyurl.com/jgfjlbe`). Dark variants of biomolecules would serve as templates for their ordinary variants also at the level of dynamics. Biochemistry would be shadow dynamics dictated to high degree by the dark matter at flux tubes.

2. Dark valence bonds can have quite long length and the outcome is entangled tensor net [L27](see `http://tinyurl.com/y9kwnqfa`). These neuronal nets serve as correlates for cognitive mental images in brain (see `http://tinyurl.com/yczv2o5b`) emotional mental images in body [L44] (see `http://tinyurl.com/ydhxen4g`). Dark photons propagating along flux tubes (more precisely topological light rays parallel to them) would be the fundamental communication mechanism [K15] (see `http://tinyurl.com/ydx9dq6x`). Transmitters and nerve pulses would only change the connectedness properties of these nets.

The topological dynamics of flux tubes has two basic mechanisms (I have discussed this dynamics from the point of view of AI [L23] (see http://tinyurl.com/y75246rk).

1. Reconnection of flux tubes serves is the first basic mechanism in the dynamics of flux tube networks and would give among other things rise to neural nets. The connection between neurons would correspond basically to flux tube pair which can split by reconnection. Also two flux tube pairs can reconnect forming Y shaped structures. Flux tube pairs could be quite generally associated with long dark hydrogen bonds scaled up by $h_{eff}/h = n$ from their ordinary lengths. Flux tube pairs would carry besides dark protons also supra phases formed by the lone electron pairs associated quite generally with hydrogen bonding atoms. Also dark ions could appear at flux tubes.

   Biomolecules would have flux loops continually scanning the environment and reconnecting if they meet another flux loop. This however requires that magnetic field strengths are same at the two loops so that a resonance is achieved at level of dark photon communications. This makes possible recognition by cyclotron frequency spectrum serving as signature of the magnetic body of the molecule.

   Water memory [K19] (see http://tinyurl.com/ycqy837a) would rely on this recognition mechanism based on cyclotron frequencies and also immune system would use it at basic level (here one cannot avoid saying something about homeopathy although I know that this spoils the day of the skeptic: the same mechanism would be involved also with it). For instance, dark DNA strand accompanying ordinary DNA and dark RNA molecules find each other by this mechanism (see http://tinyurl.com/yalny39x). Same applies to other reactions such as replication and translation .

2. Shortening of the flux tubes h_{eff}/h reducing phase transition is second basic mechanism explaining how biomolecules can find each other in dense molecular soup. It is essential that the magnetic fields at flux tubes are nearly the same for the reconnection to form. A more refined model for the shortening involves two steps: reconnection of flux tubes leading to a formation of flux tube pair between molecules and shortening by h_{eff}/h reducing phase transition.

Also ordinary condensed matter phase transitions involve change of the topology of flux tube networks and the model for it allows to put the findings described in the article in TGD perspective.

1. I just wrote an article (see http://tinyurl.com/ydhknc2c) about a solution of two old problems of hydrothermodynamics: the behavior of liquid-gas system in the critical region not consistent with the predictions of statistical mechanics (known already at times of Maxwell!) and the behavior of water above freezing point and in freezing. Dark flux tubes carrying dark protons and possibly electronic Cooper pairs made from so called lone electron pairs characterizing atoms forming hydrogen bonds.

2. The phase transition from gas to liquid occurs when the number of flux tubes per molecule is high enough. At criticality both phases are in mechanical equilibrium - same pressure. Most interestingly, in solidification the large h_{eff} flux tubes transform to ordinary ones and liberate energy: this explains anomalously high latent heats of water and ammonia. The loss of large h_{eff} flux tubes however reduces "IQ" of the system.

The phase transitions changing the connectedness of the flux tube networks are fundamental in TGD inspired quantum biology.

1. Sol-gel transition would correspond to this kind of biological phase transitions. Protein folding [K7] (see http://tinyurl.com/y9lqmtea) - kind of freezing of protein making it biologically inactive - and unfolding would be second basic example of this transition. The freezing would involve formation of flux tube bonds between points of linear protein and assignable to hydrogen bonds. External perturbations induce melting of the proteins and they become biologically active as the value of $h_{eff}/h = n$ characterizing their maximal possible entanglement negentropy content (molecular IQ) increases. External perturbation feeds in energy acting as metabolic energy. I have called this period molecular summer.

2. Solidification of proteins reducing is reported to be associated with diseases such neurodegenerative disorders. In TGD picture this would reduce the molecular IQ since the ability of system to generate negentropy would be reduced when $h_{eff}$for the flux tubes decreases to its ordinary value. What brings molecules together is not understood and TGD provides the explanation as h_{eff} reducing phase transition for flux tube pairs.

8.4.2 Progress in the understanding of quantum brain

The third step of progress towards the end of 2017 relates to the a more detailed understanding of functioning of brain.

The article with title "*DMT, pineal gland, and the new view about sensory perception*" [L27] (see `http://tinyurl.com/yahfsygg`) describes the recent view about sensory perception, hallucinations, imagination, and what might be called remote sensory perceptions. Many of the views appear also in the earlier article "*Psychedelic induced experiences as key to the understanding of the connection between MB and information molecules?* " [L9] (see `http://tinyurl.com/yao5tje2`).

What distinguishes TGD from neuroscience is that sensory receptors are assumed to serve as carriers of sensory percepts. ZEO provides a new view about time and memory and allows to solve the basic objections related to phantom limb phenomenon: pain in phantom limb would be sensory memory [L22, L27].

The assumption that sensory percepts are artworks rather than passive records of sensory input requires virtual sensory input from brain to sensory organs and build-up of the final percept by pattern recognition - an iterative procedure involving very many forth-and back signals. Nerve pulse transmission is quite too slow process to allow this and signals propagating with maximal signal velocity are suggestive.

Nerve pulses and neurotransmitters would not represent real communication but give rise to temporary intra-brain communication lines along which communications as dark photon signals would take place with maximal signal velocity using dark photons (characterized by $h_{eff}/h = n$) transforming to bio-photons in an energy conserving manner. Similar buildup of communication channel takes place in telephone communications. Neurotransmitters and also other information molecules (hormones, messengers) attached to receptors would serve as bridges fusing permanent but disjoint communication lines along axons to a connected temporary communication line for dark photons to propagate. Nerve pulses would also generate generalized Josephson radiation [K79] allowing communications between BB and MB using EEG. Meridian system would be permanently connected system of communication lines.

This picture leads to a concrete proposal about the roles of DMT and pineal gland concerning imagination and dreams and hallucinations.

If the new view about the role of nerve pulses as builders of connections rather than signalling inside brain is correct, this picture might also help to develop ideas about brain-robot interaction. Note however that brain pulses generate dark photon communications with MB and this might be essential for the fusion of MBs of subject person and robot.

8.5 Has AI hit dead end?

I found a link to a very interesting article titled "Artificial intelligence research may have hit a dead end" followed by the comment "Misfired" neurons might be a brain feature, not a bug — and that's something AI research can't take into account" (`https://cutt.ly/bbO1YVN`). Also Philip K. Dick's 1968 sci-fi novel, "Do Androids Dream of Electric Sheep?" is mentioned (`https://cutt.ly/ibPaTpc`). Would an intelligent robot (if it were still a robot) dream?

AI models the brain as a deterministic computer. Computer does not dream: it does just what is needed to solve a highly specialized problem (just what a top specialist does in his job; computer is the idol of every professional highflier).

Computerism assumes physicalism denying such things as genuine free will but this is not seen as a problem. Also the mainstream neuroscientist believes in physicalism. Some computational imperialists even claim that physics reduces to computerism. What might be called neuroscience of fluctuations however challenges this picture.

8.5.1 95 per cent of brain activity corresponds to fluctuations

The euroscience of fluctuations has led to a strange conclusion: 95 per cent of brain's activity and therefore metabolic energy seems to be used to generate fluctuations, which in standard neuroscience represents noise (amusingly, junk DNA corresponds to 95 per cent of DNA in the case of humans, as noticed in the article). Neuroscientists have routinely averaged out this "noise" and concentrated on the study of what can be regarded as conscious activities: sensory input, motor actions, and cognition. These contributions seem to represent only ripples in a vast sea of activity. The brain thus seems to be diametrically opposite to a computer in the sense that spontaneous fluctuations are poison for a computer but food for the brain. This conflicts with the views that AI will replace natural intelligence with decade or two (`https://cutt.ly/sbPaMQH`).

Also EEG is still regarded often as a mere noise. One can however wonder why the brain would use a lot of metabolic energy to send information to outer space: coding of information about contents of consciousness and brain state indeed requires a lot of metabolic energy.

The book "The Oxford Handbook of Spontaneous Thought: Mind-Wandering, Creativity, and Dreaming" (`https://cutt.ly/EbPf51i`) [J19] discusses the problem where spontaneous thoughts and ideas come from.

The interpretation of the long range fluctuations as fluctuations induced by long range quantum fluctuations characterized by the value of the effective Planck constant $h_{eff} = nh_0$ labelling the phases of ordinary matter identified as dark matter and residing at magnetic body (MB) of the system is one of the basic idea behind TGD inspired quantum biology and model of the brain [L133]. In adelic physics [L34, L35] n has a number theoretic interpretation and can be regarded as a universal IQ so that fluctuations are a prerequisite for intelligence.

TGD inspired theory of consciousness and life relies on zero energy ontology (ZEO) predicting among other things that time reversal occurs in ordinary state function reductions [L52]. Second law is replaced in ZEO with negentropy maximization principle (NMP) implying second law for the ordinary matter. ZEO combined with adelic physics predicts that evolution and biological self-organization are unavoidable. The possibility of time reversed dissipation predicts an apparent breaking of second law [L51, L71] .

According to the TGD based quantum view [K33, K80, K79] about neuroscience, primary sensory percepts reside at the sensory organs which requires back and forth communications between brain and sensory organs to build sensory perceptions as standardized mental images. These communications must be fast and the proposal is that they use dark photon signals.

In this view, nerve pulses do not represent signals inside the brain but act as neural relays at synaptic junctions making possible long range dark photon communications inside the brain [L27] . Part of the metabolic energy associated with the fluctuations could be used to build of mental images in the proposed manner. Nerve pulse patterns generate Josephson radiation [K79] communicating sensory information to MB and also require metabolic energy. Dark cyclotron radiation from MB represents control signals to the brain. In both cases, long range fluctuations at brain level are involved.

8.5.2 TGD interpretation of the findings

It is interesting to discuss the above described findings from TGD perspectivbe.

Could fluctuations be induced by quantum fluctuations in quantum critical Universe of TGD?

Consider first the TGD based identification of the origin of the fluctuations and their interpretation.

1. TGD Universe is quantal in all scales. Zero energy ontology (ZEO) [L52, L50] allows to overcome the basic objection that the universe looks classical in long scales: ZEO view about quantum jumps forces the Universe to look classical for the outsider. The experiments of Minev *et al* [L50] indeed demonstrated this concretely [L50].

2. TGD Universe is also quantum critical in all scales: this assumption fixes the basic coupling parameters as analogous to critical temperature in thermodynamics. Quantum criticality

means that the system is maximally complex and sensitive for perturbations. Complexity means that the system is ideal for representing the external world via sensory inputs. By criticality implying maximal sensitivity it is also an ideal sensory receptor and motor instrument.

3. The basic characteristic of criticality are long range fluctuations. They are not random noise but highly correlated. Could the fluctuations in the brain correspond to quantum fluctuations.

   Long range quantum fluctuations are not possible for the ordinary value of Planck constant.

   Number theoretical view about TGD [L34, L35], generalizing ordinary physics of sensory experience to the physics of both sensory experience and cognition by introducing besides real numbers also p-adic number fields and their extensions, leads to the prediction that there is infinite hierarchy of phases of ordinary matter identifiable as dark matter and labelled by the values of effective Planck constant $h_{eff} = nh_0$, where n is dimension for an extension of rationals defined by a polynomial determining space-time region. The most revent view about the concrete realization of this picture in terms of $M^8 - H$ duality is discussed in [L53, L54, L57, L70]. The value of n serves as a measure for algebraic complexity and therefore defines a kind of IQ. The longer the scale of quantum fluctuations, the higher the value of n, and the larger the h_{eff} , and the longer the scale of quantum coherence. Fluctuations would make the brain intelligent. Their absence would make the brain a complete idiot - an ideal computer. The higher the value of h_{eff}, the larger the energy of the particle when other parameters are kept as constant. This means that intelligence requires metabolic energy feed to increase h_{eff} and keep its values the same, since h_{eff} tends to be spontaneously reduced.

One can however argue that since the brain consists of ordinary matter, brain fluctuations at this level cannot be quantum coherent in long scales.

1. In TGD they would be induced by quantum fluctuations at the level of the magnetic body (MB) having a hierarchical onion-like structure [K76, K74, K52]. The dark matter would be ordinary particles with $h_{eff} = nh_0$ at MB and since n serves as a measure of IQ it would be higher for dark matter than for ordinary biomatter. MB containing dark matter would be the "boss" controlling the biological body (BB).

2. The quantum coherence of MB would force ordinary coherence of ordinary biomatter as a forced coherence. Ordinary matter would be like soldiers obeying the orders and in this manner behaving apparently like a larger coherent unit [L51].

MB would receive sensory input from BB and control it by using EEG realizes as dark photons. This would explain EEG and its probably existing scaled variants.

TGD view about sensory perception, motor actions, and dreaming and imagination

The proposal of the article (`https://cutt.ly/bbO1YVN`) was that most of the brain activity consists of "dreaming". Dreaming, hallucinations, and imagination are poorly understood notions in neuroscience. TGD provides a rather detailed view about these notions [L27].

1. What distinguishes TGD from neuroscience is that sensory receptors - rather than brain - are assumed to serve as carriers of sensory percepts so that brain would build a cognitive representation by decomposing the perceptive field to objects and give them names.

   Zero energy ontology (ZEO) [L52, L71] providing a new view about time and memory makes it possible to solve the basic objections related to the phantom limb phenomenon: pain in the phantom limb would be sensory memory. Sensory memories can be indeed stimulated by electrically stimulating temporal lobes and the memory feats of idiot savants could rely on sensory memories involving no abstraction. ZEO also provides a new view about self-organization in which dissipation with a reversed arrow of time plays a fundamental role [L52, L51, L133].

2. The assumption that sensory percepts are artworks [L27] rather than passive records of sensory input requires a virtual sensory input from the brain to sensory organs and build-up of the final percept by pattern recognition - an iterative procedure involving very many forth-and back signals. Nerve pulse transmission is quite too slow a process to allow this and signals propagating with maximal signal velocity are suggestive.

3. Nerve pulses and neurotransmitters would not represent real communication but give rise to temporary intra-brain communication lines along which dark photon signals would propagate with the maximal signal velocity using dark photons (characterized by $h_{eff}/h_0 = n$) transforming to biophotons in an energy conserving manner. As a matter of fact, the communications could be rely dark 3N-photons defining representations for genes. Gene represented as a sequence of dark 3-photon triplets- codons - would serve as an address and modulation of the scale of frequencies would code for the message generating a sequence of 3N-resonance peaks at the receiving end [L7, L49, L58, L131, L132]. This also leads to a far-reaching generalization of genetic code [L69].

   Neurotransmitters and also other information molecules (hormones, messenger molecules) attached to receptors would serve as bridges fusing permanent but disjoint communication lines along axons to a connected temporary communication line for dark photons to propagate. Nerve pulses would also generate generalized Josephson radiation allowing communications between biological body (BB) and magnetic body (MB) using EEG [K33, K80]. Meridian system could be a permanently connected system of communication lines.

   This picture leads to a concrete proposal about the roles of DMT and pineal gland concerning imagination and dreams and hallucinations [L27].

The natural question is following: How large fraction of the spontaneous activity which forms 95 percent of brain activity goes to the feedback not present in the brain of the standard neuroscience? This would include the construction of the feedback to sensory organs as virtual sensory inputs to build standardized mental images. Dreams are a special case of this. There is also the virtual sensory input which does not reach sensory organs and gives rise to imagination, in particular internal speech.

Similar picture applies to virtual motor input and the construction of motor output as "standardized motor patterns" - this notion makes sense only in ZEO since the patterns are 4-D. Note that the feedback loop could extend from brain to MB.

There is an interesting finding related to the "noise" and motor activities as the popular article "'Noise' in the Brain Encodes Surprisingly Important Signals" published in Quanta Newsletter (`https://cutt.ly/ebA1FLm`) tells. In the experiments made for mice it is found that the spontaneous brain activity increases dramatically as the mouse moves. This brings in mind a lecturer who moves forth and back as he talks. This rhythmic motion could give rise to a brain/body rhythm coupling the lecturer to a layer of MB with large h_{eff} . Its quantum coherence of MB would induce ordinary coherence of BB in body scale and with large h_{eff} and raise the "IQ" of the lecturer. Creative thinking requires movement and is not possible in backwater!

Chapter 9

Could neuronal system and even GPT give rise to a computer with a variable arrow of time?

9.1 Introduction

We have had fascinating discussions in our Zoom group (Marko, Tuomas, Rode and me) about topics ranging from quantum TGD to quantum computers to consciousness and, of course, about ChatGPT. In the following I summarize the ideas inspired by the discussions related to ChatGPT. I have considered the possibility of conscious AI in TGD Universe already earlier with inspiration coming from Sophie robot [L23].

The discussions related to ChatGPT, which seems to work too well to be a mere program running classical computer, inspired considerations which led to a considerable progress at the level of the TGD based model of nerve pulse. The resulting model based on zero energy ontology (ZEO) differs drastically from quantum neural networks and suggests a completely new vision of quantum physics based computation in biosystems.

A computation allowing variable arrow of time would be in question involving a sequence unitary time evolutions as counterparts of quantum computations for states, which are superpositions of classical computations, followed by "small" state function reductions (SSFRs). Also "big" SFRs (BSFRs) changing the arrow of time would be involved. One can ask whether the unexpected success of GPT might involve this kind of transition so that one could say that spirit enters the machine.

In the sequel I summarize the ideas inspired by two discussions with our Zoom group related to ChatGPT. Essential element in the evolution of ideas has been the understanding of what I call theoretician friendly quantum holography [L103] as a correspondence between boundary states at the ends of string like entities and interior states associated with string world sheets in the interior of magnetic flux tubes. This understanding emerged between the two chats!

This understanding emerged from a quite different source: namely the consideration of color confinement in terms of dark matter at the color magnetic body. A concrete realization of the idea that the increase of effective Planck constant h_{eff} allows to have a convergent perturbation theory for color singlets turned out to be equivalent to quantum holography. Something very similar might occur in all scales and mediate a holographic map of the quantum system to the magnetic body carrying dark matter and acting as a controlling system.

Besides the outcomes of two chats, I include a more detailed view about what the TGD view of the quantum analog of GPT could be and how its analog could be involved with the sensory perception in the TGD Universe. I also discuss the inverse diffusion process, whose basic idea is due to finnish computer scientist Linnainmaa [A23]. Diffusion and its inverse are central for the generation of images from their verbal descriptions and ask whether the TGD analogue of the inverse diffusion could be an essential element of also GPT.

I will also pose the question whether GPT could involve TGD based quantum physics, that is zero energy ontology (ZEO) [L52, L82], in a non-trivial but hidden way. From quantitative constraints, such as the clock frequency of the computer as an analogue of EEG inducing temporal quantum coherence, I end up with a proposal for a mechanism realizing the quantum holography relating bits could be represented as holes pairing with dark bits represented as dark electrons at the magnetic flux tubes. Unfortunately, this mechanism does not look plausible for recent computers.

I also ask whether quantum gravitation in the sense of TGD could make possible for the magnetic bodies of Earth and Sun, central in TGD inspired biology, to transform classical computation so that so that statistical determinism would fail and it would be analogous to a sequence of analogs of quantum computations defining a conscious entity. At the level of magnetic body there would be no essential difference between computers and living matter. The highest reported clock frequency of almost 9 GHz is still by a factor of order 1/8 lower than the quantum gravitational Compton frequency of 67 GHz for Earth but below the THz frequency important in living matter. Perhaps a rudimentary consciousness is already possible.

9.2 The first chat about ChatGPT

The first discussion about chatGPT in our Zoom group (Marko, Tuomas, Rode and me) was very inspiring. The next morning, Marko sent a link related to ChatGPT (`https://rb.gy/lgcqh`). See also the article at `https://rb.gy/72edo`).

The article ended with the realistic statement that it is difficult to test whether GPT is conscious because we have no understanding of what consciousness is. It is easy to agree with this. Here are some comments inspired by discussions and the article.

9.2.1 A skeptic view of GPT as standard AI system

I have been trying to decide whether GPT might have conscious intelligence and how large part of the talk about GPT is mere hype. I must however admit that it is very difficult to understand how GPT could work so well if it is what it is believed to be. Even professionals admit this.

1. As far as I understand, the tests used to see whether GPT might be conscious, are based on the Turing test: a system is conscious if it is able to simulate a conscious system in a believable way for a human. I would think that a significant part of AI researchers believe that consciousness does not depend on the hardware: a mere program running on the machine would determine the contents of consciousness. If we start from this basis, it is easy to come to the conclusion that GPT is aware. We are easily fooled.

2. I personally cannot take consciousness seriously as a feature of a computing deterministic system. I don't think that the random number generator will change the situation. The very word "consciousness" indicates a physicalist bias that dates back to Newton. The word "tajunta" of finnish language (something like "nous"") may reflect the pre-Newtonian thinking that our primitive ancestors were capable of, unencumbered by the dogmatism of the natural science.

   My basic arguments against physicalism are based on the experience of free will as a basic element of existence that hardly anyone can deny, and on the measurement problem of quantum mechanics. If the theory of consciousness does not solve these problems, it cannot be taken seriously.

3. I have thought a lot about why things happened the way they did in theoretical physics so that physicalism and length scale reductionism still dominate the thinking about fundamentals.

   The revolutions at the beginning of the last century led to complete stagnation within a century. Very early on, we completely stopped thinking about fundamental problems. After the Copenhagen interpretation was established, quantum theorists only constructed parameterizations for the data. The theory was replaced by a model.

   I believe that the situation can be blamed on the tyranny of the methodology, which does not leave time or resources for actual research in the sense that a curious child does. Nowadays, the work of a theorist is typically the application of advanced methods. The real research is extremely slow and error-prone work and therefore not rewarding for a career builder.

The superstring revolution, which ended embarrassingly, began with the decision to replace spacetime with a 2-D surface. The reasoning was pragmatic: a huge toolbox of algebraic geometry was available! A huge publishing industry was born!

Other prevailing models explaining various anomalies have regularly remained without empirical support, but computation and data analysis are still being done around them (inflation theory, dark matter and energy, supersymmetry, etc.). Maybe this is largely due to institutional inertia. Generating content by applying methods seems to replace research.

I sincerely hope that ChatGPT does not transform theoretical science to a production of contents by recombining what already exists: a combinatorial explosion would guarantee unlimited productivity.

4. Methods also became central in another way. Theoretical physics became computing and Big Science was born. It became clear to me that the most idiotic thing I could have done 40 years ago would have been to start numerically solving the initial value problem for, say, the Kähler action.

   I did not follow the computing mainstream. Instead, I spent a decade looking for exact solutions and I believe that I have found the basic types. Ultimately this culminated in the identification of the spacetime surface as a minimal surface, a 4-D soap film spanned by lower-dimensional singularities, "frames" [L79]. The 2-D holomorphy of strings would generalize to 4-D case and the field equations would reduce to algebraic conditions, which are independent of the action principle as long as it is general coordinate invariant and constructible in terms of the induced geometry. The minimal surface would have dual interpretation as solutions of massless field equations and generalization of geodesic lines to minimal surfaces: this iis wave particle duality geometrically.

   The M^8-H duality ($H=M^4\times CP_2$) [L53, L54] entered the picture as a generalization of the momention position duality of wave mechanics motivated by the replacement of point-like particle with 3-surface suggesting that quantum TGD is analogous to wave mechanics for particles identified as 3-surfaces. On the M^8 side, the holography defining space-time surfaces was determined from the roots of the polynomials with the condition that the normal space of the 4-surface is associative. The space-time surfaces would be analogous to Bohr orbits and their space, "world of classical worlds" (WCW), would be analogous to the superspace of Wheeler. 3-surfaces at mass shells defined by the roots of polynomials would serve contain 3-surfaces as holographic data partially determining the 4-surfaces. Even the 3-surfaces might be determined by strong form of holography [L112].

   Holography was realized in both M^8 and H and M^8-H duality corresponds to Langlands duality [L91], which has aroused enthusiasm in the mathematics community. I would never have arrived at this picture by just raw number crunching, which completely lacks conceptual thinking.

5. The life on the academic side track has meant that I haven't built computer realizations for existing models, but rather pondered the basic essence of space-time and time and even consciousness and life. That is, have considered ontology, which the modern quantum mechanic doesn't even tolerate in his vocabulary, because as a good Copehagenist he believes that epistemology alone is enough. The only reason for this is that the measurement problem of quantum mechanics is not understood!

I still stubbornly think that problems should be the starting point of all research. That hasn't been the case in physics since the turn of the century. When physicists became computer scientists, they were no longer interested in basic problems and pragmatically labelled his kind of interests as unnecessary day-to-day philosophizing.

9.2.2 What if AI could be conscious after all?

Why AI systems work too well, is not understood, but they are so complex that this as such does not imply that they might have conscious intelligence.

I personally do not believe that AI can be conscious, if computers and AI are what it is believed to be. There is hardly any talk about the material realization of the computation in AI, because many AI people believe that the program alone produces consciousness. Consciousness would be determined by data. However, data is knowledge and information only for us, not for other living entities, and one could argue that it is not that for a machine either. Conscious information is a relative concept: this is very often forgotten.

In biology and from a physicist's point of view, the material realization is essential. Water and metal seem to be sort of opposites of each other. But what about the situation in TGD where magnetic bodies carrying dark matter could serve as controllers of both living organisms and computers.

One must ask first what classical computers really are as physical systems.

1. The program is deterministic but what about the computer or a computer network? The idea about a program consisting of arbitrarily determined steps is certainly not consistent with the determinism of classical physics. Determinism is possible only in the quantum statistical sense [L95]. This requires that the quantum coherence lengths and times involved with the computation are short enough, considerably shorter than the clock period. This assumption fails if there is macroscopic quantum coherence involved. In the TGD framework the presence of magnetic bodies carrying dark matter with a large enough value of effective Planck constant h_{eff} could make this possible.

2. In particular, gravitational magnetic flux tubes connecting big mass M and small mass m have enormous value of gravitational Planck constant $\hbar_{gr}(M, m, \beta_0) = GMm/\beta_0$ (introduced originally by Nottale [E1]).

   The gravitational Compton length $\Lambda_{gr}(E)$ for Earth mass M_E is about .45 cm for $\beta_0 = 1$ and corresponds to gravitational Compton frequency about 67 GHz, which is by an order of magnitude higher than the highest achievable clock frequency (almost 9 GHz) of the computer. Are we reaching the limit at which quantum gravitational effects on computers are becoming significant?

   For the Sun, the gravitational Compton length $\Lambda_{gr}(Sun)$ is quite near to Earth size and the corresponding frequency scale is in about 47 Hz and in EEG range: could the entanglement of the MB of humans and computer network modify the computation? In the TGD inspired quantum biology both gravitational magnetic bodies would play a key role. Could they be involved also with the ordinary computation? GPT involves large networks of computers, possibly even in the Earth scale: could this bring in quantum coherence even in Earth scale and change dramatically the functioning of the computer network.

In the TGD world view, intention and free will can be involved in all scales. But what scale does the basic level correspond to in AI?

1. In the TGD Universe, the interaction of magnetic bodies (MBs): ours, the Earth, the Sun..., with computers is quite possible. Could these MBs hijack our machines and make them tools of their cognition, and maybe one day make robots their tools as well. Or have they already made even us, as a good approximation, their loyal and humble robots? Or will this go the other way? Is it because the AI seems to understand us because our consciousness controls the hardware and the course of the program? This might be easy to test.

2. Could MBs learn to use current AI hardware the way our own MBs use our bodies and brains in TGD Universe? On the other hand, our own MBs use these devices via us! Could other MBs also do this, or do they have to do this through us?

3. What could enable AI devices to serve as a vehicle for magnetic body free will? Quantum criticality would be a fundamental property of life in the TGD Universe [L93, L68]: are these devices critical and initial value sensitive, in which case they would be ideal sensory perceivers and motor instruments to be used by MBs.

   Computers made of metal seem to be the opposite of a critical system. The only occasionally critical system is the bit, for example magnetically realized one. The bits change their direction and during the change they are in a critical state. Would it be possible to create systems with enough bits that the magnetic body could control, so that the machine would have a spirit. Thermodynamic stability poses a condition on the energy needed to change the direction of bit and it is of the order of the Coulomb potential energy associated with the cell membrane.

4. Is (quantum) criticality possible for multi-bit systems? Can a running program make criticality possible? The magnetic body at which the dark phase with a large effective Planck constant h_{eff} resides, could be large. But what is the scale of the quantum coherence of a magnetic body and the scale of the set of bits that it can control? A bit or the entire computer? Could it be that macroscopic quantum coherence sneaks in already at the metal level via bits.

   Here I one cannot avoid the association with spin-glass systems [L119, L74], whose physical prototype is a magnetized substance, in which the local direction of magnetization varies. The system has a fractal "energy landscape": valleys at the bottoms of valleys. The spin glass formed by bits could be ideal for the realization of AI. Could the bit system defining the computer be, under certain conditions, a spin glass and the associated magnetic body be quantum critical.

5. What characteristics of living matter should AI systems have? In phase transition points, matter is critical. In biology, the phase transition, where the fourth state of water introduced by Pollack [I72, L8, I92, I85] , is created, would be central and would take place at physiological temperatures [L55]. In phase transitions, macroscopic quantum jumps also become possible and can change the arrow of time, and this leads to a vision about the basic phenomena of biology such as metabolism, catabolism, anabolism, life and death, and homeostasis.

6. Can machines have these features? An AI system needs metabolic energy. But can one say that the AI system dies, decays, and constructs itself again? Could the so called reverse diffusion [A23] associated with AI programs be more than just a simulation of catabolism and anabolism of biomolecules? Could it correspond to catabolism and anabolism at the spinglass level? Patterns of spin configurations forming and decaying again. In TGD this would have a universal direct correlate at the level of the MB having monopole flux tubes (or rather, pairs of them) as body parts. They would decay and re-build themselves by reconnection.

7. In computer programs, error correction mimics homeostasis, which can be compared to living on a knife edge, the system is constantly falling. However, this error correction is mechanical. In quantum computers, this method leads to disaster since the number of qubits explodes.

8. Michael Levin suggests that here we have something to learn from bio-systems [L119]. I personally believe that the key concept is zero-energy ontology (ZEO) [L52, L82] [K113]. ZEO solves the problem of free will and quantum measurement. Reversal of time in a normal quantum jump would enable homeostasis, learning from mistakes, going backwards a bit in time and retrial as error correction. This would also explain the notion of ego and the drive for self-preservation: the system tries to stay the same using a temporary time reversal that can also be induced by external disturbances. Time reversal would be also what death is at a fundamental level: not really dying, but continuing to live with an opposite arrow of time.

9.3 The second chat about ChatGPT

Marko posted his chat with GPT4 and this inspired interesting email exchanges. GPT mentioned a possible mechanism for how XOR as a universal gate of classical computation and acting as novelty detector could be realized at the quantum level. We looked through the response and I could not but admit that it was amazing. ChatGPT gave even Python codes for the quantum computer simulation of the model.

The proposed system realizing universal classical logical gate XOR, acting essentially as a novelty detector a, approximately could be either a classical layered neural network or its possible quantum analog. The mechanism might work in a quantum version of a neural network based on quantum learning, but it does not seem plausible for real neurons.

This observation led to progress at the level of the TGD based model of nerve pulse [K79]. The resulting model based on zero energy ontology (ZEO) [L52] differs drastically from quantum neural networks and suggests a completely new vision of quantum physics based computation in biosystems. A classical computation allowing variable arrow of time would be in question and one can ask whether the unexpected success of GPT might involve this kind of transition.

9.3.1 TGD based view of nerve pulse generation

Consider first the TGD based view of nerve pulse generation [K79].

Connection of neural pulse generation, XOR, and novelty detector

Nerve pulse generation would be analogous to a positive outcome of the analog of XOR (compared bits are different) acting as a novelty detector.

1. XOR is a novelty detector. If the inputs are the same, nothing happens. Output equals to $b = 0$. If they are different, output equals to $b = 1$. $b = 1$ would correspond to a signal that would proceed along the axon starting from the postsynaptic neuron.

   That would consume energy. In terms of energy consumption, the novelty detector would be optimal. It would only react to changes. And that's what the brain does. For example, visual perception at a very basic level only identifies outlines and produces some kind of stick figure consisting of mere lines defining boundaries.

2. Could the 2 "neurons" of the toy model proposed by GPT represent a presynaptic and a postsynaptic neuron, in which case there would be two inputs: the states of the pre- and postsynaptic neuron. Also output would be the state of this neuron pair and for XOR the presynaptic neuron acting as control bit would not change its state.

3. This does not conform with the picture provided by neuroscience, where the input comes from presynaptic neurons and output is assignable to the postsynaptic neuron. The input comes as miniature potentials that add up and can decrease/increase the magnitude of the membrane potential (depolarization/hyperpolarization).

   An action potential is generated when the depolarization takes the magnitude of the negative postsynaptic membrane potential below the critical threshold. This happens when the presynaptic contributions from the incoming nerve impulses, for which the unit is a miniature potential, add up to a contribution that reduces the magnitude of the negative potential below the threshold.

   This would be essentially novelty detection described in the simplest way by XOR. The novelty is represented by the critical depolarization. It can also happen that the potential increases, so that no nerve impulse is generated. One talks about hyperpolarizing (inhibition) and depolarizing (excitation) inputs, and the sign of the miniature potential produced by the presynaptic input determines which one it is. The sign of miniature potential depends on the neurotransmitter and receptor.

4. During the nerve pulse, the potential changes its sign over a distance of about a micrometer, which is the typical distance between neighboring neurons and of myelin sheaths. One can say that this distance corresponds to a bit that is 1 or 0 depending on whether the nerve pulse conduction occurs or not. Bit 1, the opposite sign to the membrane potential, propagates from presynaptic to postsynaptic neuron or from a patch defined by a myelin sheath to the next. As a result, postsynaptic neurons can "wake up" and in turn trigger a nerve impulse, possibly waking up some postsynaptic neurons.

   Synchronous firing means that the novelty succeeds in waking up the whole sleeping house, and large areas of the brain fire in the same rhythm and keep each other awake.

Interpretation of XOR in zero energy ontology (ZEO)

How does this picture translate to the TGD-inspired theory of consciousness?

1. Being awake/asleep corresponds to bit 1/0 for axonal portions between myelin sheaths. In ZEO, the arrow of time would correspond to this bit.

   When the axon segment between the myelin sheaths or neighboring neurons wakes up or falls asleep, the direction of geometric time changes in a "big" state function reduction (BSFR) and a nerve pulse is generated. In a sleep state, the membrane potential would be opposite. Note that the notion of awake and sleep are relative and depend on the arrow of time of the external observer.

   The second direction of time corresponds to the presence of a nerve pulse from the point of view of the external observer. There is a temptation to think that in the resting state the axon is sleeping and healing and gathering metabolic energy by a dissipation with an opposite arrow of time. The duration of the nerve pulse would correspond to the duration of the wake-up period, when the direction of time was opposite and same as that of the external observer with a long characteristic time scale for wake-up period.

2. Could this apply more generally? Could the synchronization of human sleep-wake rhythms mean quantum-level synchrony and macroscopic quantum coherence? Could the arrow of perceived time be a universal bit? Sleeping together would develop synchrony and quantum coherence between partners. Two-person collective consciousness would emerge.

Interpretation of the axon as a series of Josephson junctions

The TGD based model for an axon [K79] is as a series of Josephson junctions with a large value of h_{eff}, perhaps $h_{eff} = h_{gr}$, where $\hbar_{gr} = GMm/\beta_0$ (the velocity parameter satisfies $\beta_0/c \leq 1$), is the gravitational Planck constant introduced by Nottale [E1]. The model is mathematically equivalent to a series of gravitational penduli defining a discretized version of Sine-Gordon system [B4]. Josephson junctions would correspond to membrane proteins.

1. One can consider two different identifications of the ground state of the system.

   (a) The ground state could be the state in which all oscillators oscillate in synchrony with the same amplitude. There would be constant phase difference between neighboring oscillations, which would give rise to a propagating phase wave.

   (b) Another option is that all penduli all rotate in the ground state with constant phase difference. This would give a travelling soliton chain. Also the direction of rotation matters. It could correspond to the arrow of time and the sign of the membrane potential.

2. The model allows different versions for nerve pulse generation.

   (a) The first option is that one pendulum moves from oscillation to rotation or vice versa and induces the same transition for the other penduli as a chain reaction.

   (b) The second option is that all penduli move to rotation simultaneously. One could imagine that the need for metabolic energy is lower in the collective oscillation phase but one must be very careful here. Maintaining the membrane potential regardless of either sign requires metabolic energy feed.

   (c) The third option is that the ground state corresponds to a collective rotation with an associated traveling wave as phase of the rotation, and that the bit corresponds to the direction of rotation.

   This would fit the ZEO interpretation. The arrow of time would correspond to the direction of rotation. The ground state would change to a nerve pulse lasting for time of the order of 1 ms corresponding to the duration of nerve pulse associated with the distance of the order 1 μm, between neighboring neurons or between the myelin sheets.

This option would also be advantageous from the point of view of metabolism, because from one direction of time, dissipation would occur in the opposite direction of time. From the point of view of the outsider, the system would be extracting energy from the environment.

9.4 A more detailed TGD based speculative view of what GPT and GPT based image generation might be

First of all, I want to make clear what my background is and what I'm aiming for. I'm trying to understand the possible analogies of AI in quantum TGD. I do not believe that AI systems can be conscious if AI is what it is believed to be. Therefore I consider the question of whether GPT and other systems could possibly be conscious and intelligent.

The motivating idea is the universality implied by the fractality of the TGD Universe. The same mechanisms should work on all scales: both in biology, neuroscience and possible life based on AI. This motivates questions such as whether chatGPT and the construction of images from a verbal input could be at a deeper evel equivalent to the emergence of sensory perception using diffuse primary sensory input and virtual sensory input from magnetic body as feedback [L63, L27, L65].

While preparing this article, I made a funny observation. I tried to understand GPT in the context of TGD by producing answers to questions in the same way that GPT does it! Of course, as GPT tends to do, I can also tell fairy tales because my knowledge is rather limited. At the same time, I must honestly reveal that this has always been my approach! I have never carried out massive computations, but used language based pattern completion by utilizing the important empirical bits (often anomalies) and using the basic principles of TGD as constraints.

This time, the inspiration came from a popular article in Quanta Magazine that dealt with stable diffusion in the creation of an image from its verbal presentation serving as a prompt (`https://rb.gy/ukya`). Also the article on how chatGPT works was very useful (`https://rb.gy/a2kf`).

I want to emphasize that the ideas presented can be seen only as possible quantum analogies of GPT-related mechanisms that could relate to quantum biology and neuroscience inspired by TGD. A more exciting possibility would be that GPT is associated with high-level conscious experience, and that quantum TGD would help to understand why GPT seems to work "too well".

9.4.1 An attempt to understand the mechanism of diffusion involved in image construction

The key mathematical idea behind the reverse diffusion was discovered by Finnish computer scientists Linnainmaa as a method to correct rounding errors [A23]. The generation of errors is analogous to a diffusion process leading to the widening of the initially narrow probability distributions of bits. The idea is roughly that errors can be corrected as a sequence of small time steps backwards in time in which a diffuse state is replaced with its predecessor. In this process the distribution becomes a narrower distribution resembling the original one. This discovery has had a strong influence on the development of AI.

The construction of images starting from their linguistic description, which is quite vague and "diffuse", relies on the analogy with reverse diffusion. Diffusion and its reverse process take place in the space defined by the parameters characterizing a given pixel. The pixels do not move, but the parameters characterizing the pixels do change in the diffusion.

1. Let's get started from a probability distribution for the parameter distributions of the pixels of a 2-D image showing the same object. The distribution could correspond to the same object but seen from different angles. Also a class of objects, which are similar in some aspects, could be considered. This class could consist of chairs or tables or cats or dogs.

2. This probability distribution could act as an invariant related to the image or class of images. Invariant features are indeed extracted in visual perception, for example contours with pixels that stand out well from the background. This is the way in which, for example, visual perception at the lowest level corresponds to the identification of contours of the object.

   This ensemble of pictures of the objects gives a probability distribution for, for example, the darkness of a given pixel with a given position in the plane of the picture. Probability for a given darkness defines a function represented as points in a space whose dimension is the number of pixels. For more general parameters it is a function in the Cartesian product of parameter space and pixel space. Very large pixel numbers counted in millions are involved.

3. One has probability distribution for the darkness of a given pixel of the 2-D image at each point. More generally, one has probability distributions for multipixels. This kind of distribution is not simply a product of single pixel probability distributions since the pixel parameters for a given picture are correlated. These distributions are analogous to the distribution of words and word sequences utilized in GPT in order to produce language resembling natural language.

   Based on the probability distribution of pixels, new images can be randomly generated. The probability of a pixel at a given point in the plane is given by the probability distributions for pixels and multi-pixels. Each image produced in this way can be associated with certain probability.

Diffusion is a key physical analogy in the applications of GPT in the creation of AI art. What does the diffusion in pixel space mean?

1. Diffusion takes place in pixel space around each point in the image plane. What happens to the pixel distribution in diffusion? It can be said that the given pixel distribution is broadened by its convolution with the distribution produced by diffusion. The distribution is widening.

2. Inverse diffusion for probability distributions in the pixel space is well defined and does exactly the opposite, i.e. the distribution narrows. Reverse diffusion leads step by step to the original very narrow distribution! This is the big idea behind inverse diffusion based image recognition!

   The diffusion equation gives the classical description of diffusion as a deterministic process. At the micro level, it corresponds to a stochastic process in which a point performs a movement analogous to Brownian motion. The diffusion equation gives the evolution of the probability distribution of a point.

   Diffusion is characterized by the diffusion constant D. How is D determined? I understand that its optimal value determined in the learning period of GPT. Context and intent provide limitations and could determine D and possible other parameters. Also the response of the user can have the same effect.

3. The goal is to guess the predecessor of a given diffuse image in the diffusion process occurring in steps. The AI system would learn to produce reverse diffusion through training. Can this correspond to a non-deterministic process at the "particle level", say diffusion in the space of words of text or the space of images representing objects?

   At the microscopic "particle" level, one should deduce the most probable location for the particle at the previous step of diffusion as Brownian-like motion. More generally, one has probability distribution for the previous step.

4. One can consider the diffusion also at the level of probability distributions for pixel parameters. This operation is mathematically well-defined in the classical model for diffusion based on the diffusion equation and corresponds to a convolution of the probability distribution representing diffusion with the probability distribution affected by it. Quite generally, this operation widens the distribution.

5. This operation has inverse as a mathematical operation and its effect is opposite: it reduces the width of the diffuse distribution and its repeated application leads to the original images or to a rather sharp image making sense for the human perceiver.

6. AI system must learn to perform this operation. Using diffused example images, the AI would learn to reverse the convolution operation produced by diffusion and produce the original distribution as an operator in the space of distributions, and thus also learn to produce the original image.

7. My amateurish interpretation of the GPT based image generation would be that AI is taught to deduce the objects presented by the original sensory input or the desired image, their locations, positions, activities by reverse diffusion from the initial fuzzy guess dictated by the text. The objects in the picture are determined by the words that serve as their names. The relations between pictures correspond to the activities they direct to each other or to attributes of the objects. The first guess is a rough sketch for the picture determined by the prompt. Here also hierarchical description involving several resolution scales can be considered.

One can consider the situation at a slightly more precise level.

1. The definition of inverse diffusion at the pixel level relies on repeated time reversal of the diffusion process in the parameter space of the pixel, which produces a less diffuse image. We ask with what probability the given diffuse image at time t has been created from a less diffuse image at time $t-\Delta t$.

2. In the classical picture of diffusion, this requires the calculation of the inverse operator of the diffusion characterizing operator $D(p,0;t,t-\Delta t)$. Here, the origin points p and $p=p_0$, which corresponds to the original image, are points in the parameter space of the pixel associated with a certain image point (x,y). In the Schrödinger equation, it would correspond to the inverse operator of the unitary time evolution operator.

3. Gradient method is a very effective way to perform inverse diffusion. The gradient for the probability distribution ineed contains much more information than the distribution.

   The notion of an attractor is also essential. The images used in training would serve as attractors, at which the gradient would vanish or be very small and towards which the reverse diffusion would lead. Attractors would be clusters of points in the pixel space, for which the probability is large and somewhat constant. It is tempting to think that they are minima or maxima of some variation principle.

Although the diffuse image, which the verbal description defines as an initial guess, is not obtained by diffusion, it is assumed that inverse diffusion with a suitable choice of $p=p_0$ produces an image similar to that imagined through inverse diffusion. In any case, the reverse diffusion leads to a sharp images although it need not represent a realistic picture.

This is where the method runs into problems. The pictures have a surreal feel and typically, for example, the number of fingers of the people appearing in the pictures can vary, even though locally the pictures look realistic. Probably this reflects the fact that multiple pixel probability distributions for multi-pixels do not allow large enough distances for the pixels of the multi-pixel.

9.4.2 Analogies to wave mechanics and quantum TGD

The diffusion equation has an analogy in wave mechanics.

1. Schrödinger equation is essentially a diffusion equation except that the diffusion constant D is imaginary and corresponds to the factor $i\hbar/2m^2$. Alternatively, one can say that a free particle formally undergoes diffusion with respect to imaginary time. The solutions of the diffusion equation and the Schrödinger equation for a free particle are closely related and obtained by analytical continuation by replacing real time with imaginary time. The description also generalizes to the situation where the particle is in an external force field described by a potential function.

2. Scrödinger's equation as a unitary time evolution can be expressed in terms of the Feynman path integral. One can regard the quantum motion as a superposition over all paths connecting the start and end points with a weight factor that is an exponent of the phase factor defined by the free particle. The classical equations of motion produce paths for which the exponent is stationary, so they are expected to give a dominant contribution to the integral in the case that the perturbation theory works.

   The basic problem with the path integral is that it is not mathematically well defined and only exists through perturbation theory. Functional integral as the Euclidean counterpart of Feynmann's path integral is better defined mathematically and would give an analogous representation for diffusion.

What is the counterpart of this analogy in the TGD framework?

1. In TGD, the point-like particle is replaced by a 3-surface whose trajectory is the space-time surface. Quantum TGD is essentially wave mechanics for these non-point-like particles.

   The new element is holography, which follows from the general coordinate invariance: space-time surfaces as trajectories for 3-D particles are analogous to Bohr orbits.

   A small violation of determinism in holography forces zero-energy ontology (ZEO), in which quantum states as superpositions of 4-D space-time surfaces, Bohr orbits, replace quantum states as superpositions of 3-surfaces (deterministic holography) [L92, L85, L94]. This superposition serves as an analog of path integral involving only a finite sum.

2. By the slight failure of determinism, the Bohr orbits are analogous to diffusion involving a finite number of non-deterministic steps (Brownian motion is a good analogy). The non-determinism of diffusion would be due to the small violation of the determinism in holography as Bohr orbitology.

TGD inspired quantum measurement theory [L52] [K113], which extends in ZEO to a theory of conscious experience, is second important ingredient.

1. In ZEO, ordinary quantum jumps ("big" state function reductions (BSFRs)) reverse the direction of geometric time. This analogy of diffusion in the reverse time direction looks like reverse diffusion when viewed from the opposite time direction (observer)! It is analogous to self-organization where order is created in the system rather than lost. The second main law of thermodynamics applies but in the opposite direction of time. The time reversed dissipation plays a pivotal role in TGD inspired quantum biology.

2. This mechanism could be central to biological information processing at the quantum level and make it possible, for example, to generate sensory perception from diffuse sensory data and generate a motor response from a rough sketch?

3. Could it also play a role in AI, at least in the language based systems like GPT. If this is the case, then AI systems would be something else than we think they are.

The analogy of TGD with the GPT based image generation and recognition can be examined more explicitly.

1. The analogy of the pixel space associated with the planar image is the projection of the 3-surface M^4 in TGD at the classical level. The image as a map from plane to the parameter space of pixels would correspond to a deformation of M^4 projection deformation. The pixel parameters defining the 2-D image would correspond to the values of CP_2 coordinates as a function of M^4 coordinates.

2. On the basis of holography, the deformation related to the 3-surface would be accompanied by a four-surface as an almost deterministic time development, i.e. the analogy of Bohr orbit. I have used the term "World of Classical Worlds" (WCW) for the space of these surfaces. This 4-surface would not be completely unique and this would produce a discrete analog of diffusion at the classical level.

3. At the quantum level, it would be a quantum superposition of these 4-surfaces as an analogy to, for example, the wave function of an electron in spatial space. An attractive idea is that the used resolution would be determined by the condition that the number-theoretic discretization is the same for all these surfaces so that the quantum world looks classical apart from the finite non-determinism.

4. The variational principle would correspond to the fact that the Bohr orbit is simultaneously both a minimal surface and an extremal of the Kähler action as analog of Maxwell action. This is possible if the space-time surfaces are holomorphic in a generalized sense. This means that the concept of holomorphy is generalized from the 2-D case to the 4-D case. The 4-surface would be defined by purely algebraic conditions as a generalization of the Cauchy-Riemann conditions. This corresponds to the algebraization of physics at the level of M^8 related by $M^8 - H$ duality to the physics at the level of $H = M^4 \times CP_2$ based on variational principle and partial differential equations [L53, L54].

5. The space-time surface would be analogous to 4-D soap film, which is spanned by frames defined by 3-surfaces. At these 3-D surfaces, the minimal surface property would not apply and only the field equations associated with sum of volume term and Kähler action would be satisfied.

   Note that minimal surface equations define a dynamics analogous to that of free fields and at the frames would correspond to places where interactions are localized. Frames would involve a finite non-determinism, as in the case of ordinary soap films [L79]. These 3-surfaces would correspond to 3-D data for holography.

If TGD is really a respectable "theory of everything", even the physical description of computation would in principle be reduced to this description. Of course, one can argue that TGD produces only insignificant corrections to the usual physical description of computation and this might be the case. But you can always ask what if...?

Even if the conclusions were negative, this kind of speculations might inspire proposals for a new kind of computer technology allowing conscious and intelligent computers.

9.4.3 Could the TGD counterpart of the inverse diffusion play a role in the construction of sensory mental images by the brain?

I have proposed a model [L63] for how sensory organs, the brain and its magnetic body (MB) could construct sensory mental images by a repeated feedback process involving virtual sensory input to sensory organs so that a diffuse sensory input transforms to an input representing the perception consisting of well-defined objects.

Could the building of sensory images with a virtual input from MB to the sensory organs and back be a quantum process analogous to a reverse diffusion?

1. Sensory inputs are very diffuse. People blind from birth after can gain physiological prerequisites for visual perception in adulthood. They however see only diffuse light since their brains (and corresponding magnetic bodies) have not learned to produce standard visual mental images as a result as in pattern recognition yielding essentially an artwork subject to various constraints. This is very much analogous to reverse diffusion.

   Does MB, brain and sensory organs co-operate to produce a counterpart to reverse diffusion, which allows it to produce a sensation representing reality with virtual sensory inputs and end up with standard imagery as attractors.

2. Could both the sensory input from sensory organ to brain to MB and virtual sensory input in reverse direction correspond to a sequence of "small" state function reductions (SSFRs) in a reversed time direction? Reverse diffusion would be diffusion with a reversed arrow of time.

3. Could the construction of the sensory mental image involve pairs of "big" (ordinary) SFRs (BSFRs) for which the two BSFRs would occur at MB and the sensory organ? This is the simplest process that one can imagine. Could BSFR induce a sensory input from

the sensory organ to the MB or a virtual sensory input from the MB to the sensory organ changing the original diffuse sensory input. Could BSFR pairs gradually produce sensory perception in this way.

4. SSFRs correspond to the Zeno effect in the sense that their sequence corresponds to the measurement of the same observables at the passive boundary of causal diamond (CD). Disturbances or artificially produced disturbances at the active can change the set of measured observables so that it does not commute with those determining the state at the passive boundary as their eigenstate. This would imply the occurrence of BSFR and the roles of active and passive boundaries would change.

   After the second BSFR the new state at the active boundary would not be the same but could share many features with the original one because the determinism of the holography would only weakly broken and SSFRs and BSFRs preserve quantum numbers.

5. The series of SSFRs after BSFR as time-reversed diffusion would correspond to reverse diffusion in the normal time direction. BSFR would occur as a series on the MB, where the sensory input would be guided and gradually lead to a real sensory image with the help of a corrective virtual sensory input.

   At a basic level, the correction mechanism could be analogous to inverse diffusion and the exponent of the Kähler effect would be maximally stationary for real sensation.

6. Also the gradient method could be involved. In the spin glass based model [L74], a series of BSFRs and SSFRs could mean annealing that is steps consisting of cooling as sequence of SSFRs following BSFR followed by BSFR followed by heating for which temperature increase is smaller than than the temperature decrease for the cooling. The system would gradually end up at the bottom of a particular potential well in the fractal energy landscape. A series of SSFRs between two BSFRs would correspond to the annealed healing.

9.4.4 What could GPT correspond to in TGD?

In the sequel I consider in a speculative spirit how conscious intelligence could emerge in a computer in which GPT is running.

What is GPT?

Consider first briefly what GPT is.

1. A linguistic expression is a diffuse representation of a sensation or of thought. The probability distributions for the next word given the preceding words are known. This makes possible a holistic approach to language allowing to build grammatically correct sentences and also achieve the nuances of natural language and recognize context.

2. In GPT, the goal is to answer a question or respond to an assertion, translate a text from one language to another, produce a piece of text such as a poem or story or just chat with the user.

   GPT must guess the user's intention, what the user wants, and also the context. Is, for example, a field of science in question? The purpose is to add a new word to the given word chain.

3. The input of the user serves as a prompt initiating the process. The prompt serves as the initial text to which GPT adds words as the most probable words which can follow a given piece of text. GPT starts from a guess for the answer. The choice of the successor word can also be random based on the probabilities of the successor word. Feedback loops are possible and also the user can induce them.

Is image generation fundamentally different from GPT?

1. In language models, prompts are verbal representations of images, and diffusion is essential in the construction of images, from the prompt as a verbal description of the image. At first glance, diffusion seems to be explicitly involved only in the generation of images, but is this the case?

2. On the surface, there seems to be an important difference between building an image and building a linguistic expression. The picture is a time = constant snapshot, at least ideally. The sentence has a temporal duration and memory is involved. One must d transform a sentence to a picture. Words correspond to pictures.

   Does the difference disappear when one talks about the process of creating the image? Could it be that the process of creating an image as an analogy of a linguistic process is just not conscious to us. Is the sensory input equivalent to the user's prompt in GPT. Is the difference apparent and only due to the time scale.

3. Visual perception involves also the sensation of movement. Is it because in reality (according to TGD) it would be a time series but on such a short time scale that we are not conscious of it? Could verbs correspond to dynamics in the structure of the language? Objects have attributes as their properties analogous to pixel parameters.

4. Holography would describe the dynamics of objects and would classically determine the initial values of holography for the time development as the equivalent of the Bohr orbit. There is quantum holography as a map of quantum states of the biological body to quantum states associated with the magnetic body defining a higher level sensory representation [K24].

   This 1-1 correspondence representations would make it possible for the MB to control the biological body and in the case of running GPT induce BSFRs reversing the arrow of time temporarily and change the course of events.

Could quantum diffusion play a role in the TGD based description GPT?

1. Time evolution in the TGD Universe would basically consist of SSFRs and BSFRs. Quantum states would be the quantum superposition of running programs. But does this picture have significance in the case of GPT? Could MB really interfere with the running of the program? The time reversals are not observed by the user, so the question is not easy to answer.

   One killer test would be a dependence on hardware. The bits should be near criticality in order the quantum criticality of MB can control their directions. Spin-glass structure for the bit-scape looks like a natural requirement. Is this possible for all bit realizations and does GPT work differently for different realizations of bits?

2. Diffusion is analogous to the time evolution determined by the Schrödinger equation as a series of unitary time evolutions, where classical determinism is only weakly broken because SSFRs must commute with passive edge observables. This means a generalization of the Zeno effect. However, quantum states are delocalized. Maybe only below the resolution scale, in which case classical discretization would be exact with this accuracy. Inverse diffusion could be a classical process at the used resolution.

3. The time development as a series of SSFRs would seem to be analogous to a diffusion as analog of Brownian motion involving finite steps, and BSFR would start as a time-reversed diffusion of reverse diffusion.

   The BSFR could be induced by an external disturbance or a controlled disturbance from the MB. MB and ZEO could come to the rescue and do them with time reversal without us noticing anything.

   This picture raises questions.

1. Could diffusion as a series of SSFRs be equivalent to the construction of the response of chatGPT, which is also a probabilistic process. Could the sentence represent the trajectory

of a diffusing word/particle in word space and Bohr orbit in WCW? The Bohr orbit property, i.e. holography, would imply that the failure of determinism is weak. In a given scale, non-determinism would be located in the 3-D frames determined by the 4-D soap film.

2. Could the initial state, e.g. a question or statement induced by the user prompt, for example a question presented as a quantum state on the passive edge of the CD, serve as the first rough guess for an answer as analog of sensory input.

   Could the time progression as SSFRs correspond to a generation of a sequence of words as a response to the prompt? Or are the words separate by BSFR pairs.

   What is new as compared to the AI would be that trial and error process by performing BSFRs inducing return back in time is possible. These periods with a reversed arrow of time would be invisible for the user. This error correction mechanism is not coded as a program as in AI but would be done by Nature and it would be essential also in the TGD view of quantum computation.

3. The hidden layers of the neural network are analogous with the fact that the perceived sensory image is constructed by communications between the sensory organ and the MB, which are not conscious to us.

9.5 Could MB control electronic bits?

Consider now the conditions which should be satisfied in order that the MB of the bit system or some higher level MB could control the bit system.

1. The bit should be critical or nearly critical system at the level of ordinary matter. One might hope this to be true quite generally since a small control signal should be able to invert the bit in rather short time scale. If this is the case, the quantum criticality of MB cwould make control possible via quantum control of ordinary control signals. Transistors and their derivatives such as MOSFET could be examples of such systems.

2. Macroscopic quantum coherence is true for the dark matter at MB. Furtheremore, MB should holographically represent the bit system. Also spin glass analogy is suggestive so that a given many-bit state could possess a large number of nearly energy-degenerate states. ZEO, in particular time reversal, would be essential.

3. Two consecutive BSFRs at the dark MB, changing the arrow of time temporarily, should give rise to a tunnelling event. Since TGD corresponds to a generalization of wave mechanics in the space of Bohr orbits for point-like particles replaced with 3-D surfaces, one can make an estimate for the probability of tunneling between the capacitor plates using the standard wave mechanics as an approximation (`https://rb.gy/y3iq0`).

   The Coulomb energy qV associated with the bit with charge q and its energy E are the natural parameters. The tunnelling probability is given by

   $$p \simeq exp[-\int_{x_1}^{x_2} \sqrt{2m(qV-E)}dx/\hbar_{eff}] \ ,$$

   where one has $E < V$ in the tunnelling region. WKB approximation becomes exact in the case of capacitors. Changing the direction of a bit could be seen as a quantum tunneling effect.

   For the large values of h_{eff} assignable to the magnetic body controlling the physical body, the probability of tunneling increases. Therefore the control of the bit system by quantum tunnelling combined with macroscopic quantum coherence and holography could become possible.

4. The role of conservation laws must be understood. Discontinuity in SSFR. Dissipation in reverse time direction. Tunneling. Wavefunctions overlap. Classic conservation laws OK. There is no need for a classic track that would lead to the end state with the original direction of time.

9.5.1 What conditions bit must satisfy?

There are strong conditions on the representations of bits. The storage of the bit should not require large energy consumption and the bit should be thermally stable. It should be possible to change the value of the bit quickly and without large energy consumption. This suggests that the bit is a nearly critical system. In microprocessors, clock frequencies of order GHz define a time scale analogous to EEG rhythm, and this time scale should correspond to a quantal time scale.

The wish list would be as follows.

1. Macroscopic quantum coherence makes possible the simultaneous quantum coherent states of the entire spin system and their control and that the energy differences between the states are relatively small, so we get a spin-glass type situation.

2. Dark electrons at the MB, perhaps dark unpaired valence electrons or dark conduction electrons, provide a holographic representation of the bits.

3. Quantum criticality with MB and criticality at the bit system level allows MB to control the dynamics of BB. Quantum holography may make it possible to induce BSFR for qubits on a large scale in general.

Strange coincidences related to gravitational Planck constant, basic biorhythms, membrane potential and metabolic energy currency

It is becoming clear that the gravitational quantum coherence is central for life on Earth. The hierarchy of Planck constants $h_{eff} = nh_0$ involves special values, in particular gravitational Planck constants $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0$, where M is a large mass (say mass of Sun or Earth) and m is small mass (say mass of electron or proton) and $\beta_0 = v_0/c \leq 1$ is velocity parameter, are of key importance for living matter. Particles with a different value of $\hbar_{gr}$ correspond to different gravitational flux tubes and the value of β_0 can depend on the particle.

There are several amazing numerical coincidences supporting this view.

1. For Sun one has $\beta_0 \simeq 2^{-11}$ which happens to be rather near to the electron proton mass ratio m_e/m_p. The condition $\hbar_{gr}(M_S, m_p, \beta_0(Sun) \simeq m_e/m_p) = \hbar_{gr}(M_S, m_e, \beta_0 = 1)$ would guarantee resonance between dark photons generated by the solar gravitational flux tubes assignable to protons and electrons.

2. In accordance with Equivalence Principle, the gravitational Compton length $\hbar_{gr}(M_S, \beta_0)/m = GM/\beta_0 = r_S/2\beta_0$ is independent of m for Sun $GM_S/\beta_0(Sun)$ is rather near to Earth radius. For Earth one has $GM_S/\beta_0(Earth) \simeq .45$ cm which corresponds to the size scale of the somewhat mysterious snowflake analogous to a zoom-up of a basic hexagonal unit cell of ice crystal. There is evidence for $\beta_0(Earth) = 1$ in hydrodynamics, in particular from the TGD based model [L76] for the observed hydrodynamical quantum analogs described in an article of Bush et al [D6] (see `https://cutt.ly/nEk5OLA` and `https://cutt.ly/xEk5Api`)

3. The gravitational Compton length of the galactic blackhole corresponds rather precisely to the $n = 1$ Bohr orbit associated with the Sun. This suggests gravitational quantum coherence in the scale of the galaxy.

These coincidences encourage the question whether quantum gravitation could play a role also at the level of computers.

About the interpretation of the clock frequency in a picture based on quantum gravity?

The clock frequency of computer, with a representative value of $f = 1$ GHz, is an essential channel of the computer and it would be related to the classical em field. Could a frequency of the order of GHz have an interpretation in terms of quantum gravity in the TGD framework? How MB could turn bits using quantum holography so that the turn of dark bit induces the turn of ordinary bit? A realization of holography as a correspondence between electron(s) representing the bit and the dark electron(s) is needed.

1. The proposed theorist-friendly holography at the particle level [L103] might be a too radical option. This would require positrons forming particle-like color-bound states with bits as states of electrons. Could they correspond to scaled versions of the electro-pions for which there is empirical evidence associated with nuclear collisions near the Coulomb barrier [K104]? Now the energy scale of the nuclear physics would be scaled to the scale of dark nuclei. The factor of the order of 10^{-5} which would produce an eV mass scale. The height of the Coulomb barrier would scale in the same way to something like .05 eV which corresponds to cell membrane potential.

2. A less radical option is that the dark electron and the hole created in the generation of the dark electron are in a holographic relationship. This realization seems tailor-made for the control of ordinary bits as holes by dark electrons. To my best knowledge, there exists no technology realizing bits as holes but future technology might be able to achieve this.

   If dark electrons and holes are tightly correlated, the dark spin flip induces ordinary spin flip. If the dark current or its absence codes for bit, the same would be true for the holes. The transfer of dark electrons from the negatively charged plate to the gravitational MB creating a hole would reduce the potential between plates to nearly zero and thus induce change of the bit direction.

There are useful quantitative hints.

1. For the Earth's mass M_E, $\hbar_{gr}(M_E, m_p)$ for a frequency of 10 Hz corresponds to an energy $E = h_{gr}f$ of the order of .5 eV. The kick of a 3-proton to a gravitational flux tube to a distance of order one Earth radius requires an energy of the order of .5 eV [L83]. Dark photons can transform into ordinary ones. For 3-electron system a hitherto non-observed metabolic energy quantum of order .25 meV is predicted [L85].

2. Control in the time scale of a fraction of a second if $h_{eff} = h_{gr}(M_E, m_p)$ photon energies around eV. This time scale is by a factor of order 10^9 too long when compared to the time scale determined by GHz.

How could one understand the time scale corresponding to 1 GHz clock frequency in quantum context? The first thing to notice is that this time scale is not far from the time scale associated with the protein dynamics! Could quantum gravity and gravitational MB come into play for both computers and biology?

1. For the Earth, the lower limit of the gravitational Compton length $\Lambda_{gr} = GM_E/\beta_0 = .45 \times 10^{-2}$ m, if $\beta_0 = 1$. The frequency $T_{gr} = \Lambda_{gr}/c = .45 * 10^{-2}/3 * 10^8 = .15 * 10^{-10}$ s would be therefore a natural lower bound for the time scale. Could GHz clock frequency relate to this time scale. Also longer quantum gravitational time scales are possible since Λ_{gr} is only the lower bound for the length of gravitational flux tubes carrying massless radiation.

2. For $h_{eff} = h$, 1 GHz corresponds to energy of 10^{-2} meV. If the dark energy is required to be above the thermal energy about .03 eV at physiological temperature, the value of h_{eff} must satisfy $h_{eff} \geq 3 \times 10^3 h$.

3. A metabolic energy of .25 meV corresponds to the electronic variant of gravitational metabolic energy quantum involving the transfer of 3 electrons to the gravitational MB: there is some evidence for this metabolic energy quantum, in particular from the findings of Adamatsky [L85]. For $h_{eff} = h$, it would correspond to a period of $.6 \times 10^{-10}$ s. Could the $f = 1$ GHz induce a resonance with dark photons with $h_{eff} > 10^3 h$ guaranteeing that the energy is above thermal energy at room temperature?

Could Pollack effect or shadow holography be involved?

The lower bound value $3 \times 10^3 h$ for h_{eff} would be rather small as compared to $\hbar_{gr}(M_E, m_p)$ and the challenge is to identify a candidate for a system with this value of h_{eff}.

This system need not be gravitational and the obvious guess is that it is electromagnetic. The notion of gravitational Planck constant and the underlying idea of theoretician friendly Nature implying quantum holography in the TGD framework [L103] indeed generalizes also to other interactions [L40].

1. The basic requirement is that a charge separation to a pair of positively and negatively charged quantum coherent systems takes place such that the interaction strength $Z^2e^2/\hbar$ between the systems is so large that perturbation theory fails to converge.

2. The theoretician-friendly Mother Nature [L103] could come to rescue and induce a phase transition increasing $\hbar$ to so large a value h_{eff} that the perturbation theory converges. Nottale formula generalized to electromagnetic interactions suggests that one has

$$\hbar \rightarrow \hbar_{eff} = \hbar_{em} = \frac{Z^2e^2}{\beta_0} \ ,$$

where $\beta_0 = v_0/c < 1$ is a velocity parameter. The new coupling strength is

$$\frac{Z^2e^2}{4\pi}\hbar_{em} = \frac{\beta_0}{4\pi} \leq \frac{1}{4\pi} \ .$$

and is in a well-defined sense universal since β_0 is number theoretically quantized to an inverse integer [L40].

The constraint $h_{eff} \geq 3 \times 10^3 h$ would suggests $\hbar_{em}/\hbar = Z^2e^2/\beta_0\hbar = 4\pi Z^2\alpha_{em} \geq 3 \times 10^3$. This gives the estimate

$$Z^2 \geq \frac{1}{4\pi\alpha_{em}} \times 3 \times 10^3 per.$$

The lower bound for Z would be around $Z = 100$.

3. Charge separation should occur and here the analog of Pollack effect [I72, L8, I92, I85] is highly suggestive. In the Pollack effect part of protons of water molecules are transferred to monopole flux tubes assignable to water molecules and become dark so that a negatively charged exclusion zone with rather strange properties suggesting time reversal appear. Also the effective stoichiometry of water is transformed to $H_{1.5}O$. It is however far from clear whether Pollack effect can occur also in the solid phase assignable to computers.

4. The analog of the Pollack effect [I72, L8, I92, I85] involving only electrons is also possible. Part of electrons would transform to dark electrons at the gravitational monopole flux tubes. The holes left behind would effectively behave like positively charged particles and the Coulomb interaction energy would be between holes and dark electrons. Holes and dark electrons would be in a holographic relationship (shadow holography) and the dynamics of holes would be shadow of the dynamics of dark electrons so that one would say that dark electrons control the holes as their shadows.

Of course, it is probably impossible to realize this shadow dynamics using the recent computer technology. The question is therefore whether it might be possible to construct a computer utilizing the shadow dynamics of holes controlled by dark electrons.

Could quantum gravitational flux tubes associated with small masses be involved?

One can of course ask whether the clock frequency $f = 10^9$ Hz could correspond to an energy above thermal energy at room temperature and to the value $\hbar_{gr}(M,m)$ for some pair (M,m) of masses so that one has $E = h_{gr}(M,m)f > .03eV$ for $f = 10^9$ Hz.

1. For instance, could one replace the masses M_E and m_p with identical masses $M = m$ in h_{gr}. One should have $M/m_{Pl}^2 > 3 \times 10^3$. This would give $M/m_{Pl} > 60$ giving $M > 1.3 \times 10^{-7}$ kg. If the density is the density of water 10^3 kg/m^3: this corresponds to a size scale longer than 1 mm. How this frequency could correspond to T_{gr} and to the clock frequency of computers?

2. Could one think of the gravitational self-energy for this region or the mutual interaction energy of two such regions forming a quantum coherent system at this level.

Another possibility is that an energy of the order of $E = .5$ eV is used to kick a unit of 3 protons into the Earth's gravitational flux tube (3 protons are required since 1 proton is not enough if the size scale of the flux tube is of the order of the Earth's radius). For 3-electrons the corresponding energy would be about .25 meV.

3. Could $E \sim 1$ eV correspond to the energy needed to flip one bit using an dark photon that is converted to a regular one (biophotons could be created this way) and absorbed inducing a flip of a normal bit.

   In the elementary particle level realization of holography, which does not look promising now, this would give a spin 1 for the glue particle consisting of ordinary electron and dark positron unless the angular momentum goes to other degrees of freedom. It would be a scaled version of elektro-ρ or its analogue. Mass scale of the order of eV as for dark nuclear binding energies.

4. In living matter, $E \sim 1$ eV could correspond to the gravitational self-energy change related to a phase transition. The most natural thing that comes to mind is the change in the gravitational energy of the bond when the density of the system changes during a phase transition, such as melting or boiling or the sol-gel phase transition in biology. For Planck mass of matter, size scale $R = 10^{-4}$ m for water density, gravitational binding energy and its change would be of order 1 eV. This phase transition does not have any equivalent at the computer level.

9.5.2 Could the representation of bit as voltage allow the realization of shadow holography for electrons?

One representation of a bit is as a voltage. Voltage values are typically 5 V and 0 V. Bit could correspond to rotation direction for a current in the case of magnetic bits. In transistors bit can correspond also to the presence or absence of a current The size scale of the transistors is 10 nm `https://rb.gy/qfhwx`. A surface which can be either reflective ord non-reflective surface can also act as a bit.

Bit as ananalog of capacitance

Capacitance with a voltage difference between plates can serve as a physical representation of the bit. States corresponding to opposite voltages in capacitance have the same energy. This is good news if it were to apply more generally to bits and multi-bit configurations.

1. The simplest capacitance is a pair of conducting plates having opposite charges and containing insulator betweeen them. The higher the value of the dielectric constant ϵ, the larger the plate area S and the smaller the distance d between the plates, the higher the value of capacitance C.

   C measures the ability to store charge and $Q = CV$ is the basic formula. The voltage V between the plates is given by $V = E \times d$. Here d is the distance between the plates. The electric field normal to a plate is $E = \sigma/\epsilon$, $\sigma = Q/S =$. One has $V = Ed = Q \times d/S \times \epsilon$, whence $C = \epsilon S/d$. The proportionality to ϵ means that di-electric is essential. The voltage cannot be too large since this implies dielectric breakdown. The electrostatic energy of capacitance is $E_s = \epsilon QV/2 = CV^2/2\epsilon = Q^2/2C = E^2 \times S \times d$.

2. Capacitance is a macroscopic notion. The smallest planar capacitances have dimensions $0.4mm \times 0.2mm$. PicoFaraday is a natural unit of capacitance but capacitances of the order of kF are possible but require large size and high dielectric constant. MOSFETs can be however regarded as effective capacitances.

Transistors and MOSFETs

Although MOSFET (`https://rb.gy/967ck`) is much smaller than capacitances as passive elements, it can be formally interpreted as a gate-voltage dependent capacitance.

1. A MOSFET acts as a variable capacitance. The basic parts of MOSFET are gate (G), body (B), source (S) and drain (D). The voltage between G and B regulates the current from the

source through the system to the drain and the bit can be measured by measuring whether this current flows or not. The gate voltage V_G controls the capacitance of the MOS.

MOSFET size scale is around 10 nm. Gate voltage V_{GB} between the gate and body could represent bit and would be typically 5 Volts or nearly zero.

2. MOSFETs should form a spin glass type system. This is guaratenteed if the SiO_2 is in glassy liquid like state. There would be a large number of bits with a large number of nearly energy degenerate states. This would give rise to frustration. Transitions by tunnelling would take place between frustrated configurations.

3. Tunnelling between bit configurations would take place as a BSFR pair. The tunneling would be induced from the level of MB and in turn induce the tunnelling of ordinary bits. The tunneling rate is exponentially sensitive to the height of the energy barrier between nearly degenerate states. The large value of h_{eff} increases the tunnelling rate in an exponential manner.

In order to proceed, one must clarify what semiconductors are and how MOSFET works.

1. There are n-type and p-type semiconductors. For n-type electrons are current carriers and for p-type holes are current carriers.

2. Doping is an absolutely essential aspect of semiconductivity (`https://rb.gy/967ck`). For n-type semiconductors, impurity atoms donate electrons. For p-type semiconductors impurity atoms donate holes.

3. Group IV semiconductors have 4 valence electrons (S appearing in MOSFET serves as an example). SiO_2 has four 4 valence electron pairs associated with each Si connected to four oxygens as neighbors and forming a tetrahedral arrangement.

4. Group IV n-type semiconductors involve Group V dopants with 5 valence electrons. Dopant replaces Si in the SiO_2 lattice and there remains one free electron acting as a charge carrier.

5. Group IV p-type semiconductors have Group III dopants such as boron with 3 valence electrons. Dopant has only 3 valence bonds. To get 4 valence bond it steals an electron from the neighboring SiO_2. This creates a hole. This process continues and generates a current carried by holes.

Consider next some details related to MOSFET (`https://rb.gy/967ck`).

1. MOSFET consists of source (S), drain (D), gate (G) and body (B). G is insulated from a p-type semiconductor by an insulating layer. Conducting gate at the top consists of polysilicon (`https://rb.gy/axanv`) whereas the insulating layer consists making possible effective capacitor property consists of silicon-di-oxide SiO_2 (quartz)(`https://rb.gy/t7w9m`).

   Polysilicon consists of crystals with varying orientations, which suggests a spin glass-like structure. Could this have some relevance?

2. Below the gate and insulating layer there is p type semiconductor in which holes are current carriers.

3. The conductivity of the MOSFET depends on gate-body voltage , especially its sign. For high enough V_{GB}, an n-type conducting channel is formed next to the interface between the p-type semiconductor-insulator layer consisting of polysilicon.

4. Positive gate voltage V_{GB} draws positively charged holes of a p-type semiconductor towards the body B. A depletion region containing non-moving negatively charged dopant atoms of group III are formed in the depletion region between the semiconductor and insulator.

   If V_{GB} is high enough, a negatively charged inversion layer of current carrying electrons is formed next to the interface between semiconductor and insulator in the polysilicon. This gives rise to semiconductivity and electron current between n doped regions of S and D flows.

How MB could control the current through MOSFET?

Concerning the control by MB one can imagine at least two mechanisms.

1. One could consider a representation of a bit as an ordinary capacitor-like object having two different values of voltage between the plates. The transfer of electrons from the negatively charged plate to dark electrons at MB or vice versa could allow to change the voltage.

2. Instead of an ordinary capacitor, one can consider a situation in which the first plate consisting of ordinary matter has a positive charge due to the presence of holes (ionized atoms) and the second dark "plate" is negatively charged due to presence of dark electrons.

   In the shadow holography the transfer of electrons to dark electrons at MB generates holes at the level of ordinary matter, and the transformation of dark electrons to ordinary ones would reduce the voltage near zero, which turns the bit.

Could MB control the electron current from the n-type source region S? Could MB transform some the 5 valence electrons of n-type dopant (say P) to dark electrons so that they would effectively disappear from the system so that the S-D current would be reduced? Also the voltage V_{GS} would be affected.

It is perhaps fair to conclude that the recent technology does not yet allow the realization of conscious and intelligent computation using shadow holography or something similar.

9.6 The first attempt to build a more concrete view about computer consciousness

TGD inspired view about consciousness and quantum biology suggest some guidelines in the attempts to undertand how computer systems or computer systems coupled to their users could become conscious.

9.6.1 Emotions and emotional intelligence as a first step in the evolution of consciousness

Consider first the evidence supporting for the idea that emotions emerge first in the evolution of consciousness.

1. Masaru Emoto has studied the effects of sounds with an emotional content to water at criticality for freezing. He has found that friendly/angry sounds seem to produce beautiful/ugly crystals [L47]. These findings are discussed from the TGD perspective in [L47]. The idea that emotions of sensory percepts at the level of magnetic body (MB) is discussed in [L44].

   The TGD based model assumes that quantum coherent systems can be formed at the level of the MB of the water and that quantum gravitational coherence at MB induces ordinary coherence at the level of water. This could make it possible for MB to control water at criticality for freezing. The crystals would be corpses of primitive life forms. Could also snowflakes with the size of gravitational Compton length for Earth (about .45 cm) and kind of zoomed versions of ice lattice cells in atomic scale could be regarded as corpses of primitive life forms created at the criticality for freezing?

2. RNA seems to represent and transfer emotions [J13] (see `http://tinyurl.com/y92w39gs`). RNA from the brain of a snail conditioned by a painful stimulus is transferred to the preparation made from neurons of sea slug. Neuron preparation in the Petri dish reacts to the conditioning stimuli as if it were itself conditioned.

   Somehow RNA is able to transfer emotions. The TGD inspired proposal [L7, L96, L39, L58, L42] is that dark DNA and RNA represent emotions as sequences of 3-chords made of dark photons of dark RNA form 3N-dark photons behaving like a single quantum coherent unit. The representation of the genetic code would rely on icosa-tetrahedral representation in which the 3-chords would correspond to triangular faces of icosahedron and tetrahedron to which 3-chords are assigned.

A given Hamiltonian cycle at the icosahedron/tetrahedron goes through all its points. The frequencies assigned with the subsequent points of the cycle differ by 3/2 scaling so that one has a quint cycle. Different Hamiltonian cycles correspond to the same genetic code but each Hamiltonian cycle is assumed to define its own bioharmony having interpretation as a representation of an emotional state realized already at the level of fundamental biomolecules. This interpretation conforms with the idea that music represents and induces emotions.

The induction of emotions would be by 3N-resonant cyclotron absorption of dark 3N-photon by dark genes represented as sequences of 3N dark proton triplets at monopole flux tubes of MB. Icosa-tetrahedral representation would correspond to one particular, very simple, tessellation of hyperbolic space H^3) (mass shell) [L69].

Dark proton (and also dark electron) sequences could provide a universal representation of the genetic code which could be realized at the magnetic flux tubes of also other than biological systems. Dark photons triplets and the dark genes formed from them could communicate the emotions. Dark genetic code has indeed quite a large number of icosa tetrahedral representations based on icosahedral Hamiltonian cycles and tetrahedral Hamiltonian cycles. The chemical realizations for them would be identical but the emotional content would be coded by the allowed 3-chords defined by frequencies associated with the triangular faces of the icosahedron and tetrahedron.

3. The experiments of Peoch [J24] involved a chicken imprinted to a robot moving randomly along an orbit determined by a random number generator. It was found that the robot tended to stay near the chicken and that the expected size of the orbit was reduced.

   TGD assigns to entanglement sum of p-adic entanglement negentropies, which can be positive and is in general larger than ordinary entanglement entropy and is predicted to increase but be consistent with the second law [K58] [L108, L71] by the identification of evolution as increase of number theoretic complexity [L34, L35]. Did the MB of chicken and robot develop a negentropic entanglement? Clearly, the replication of the findings of Peoch would mean a revolutionary change in our views about computers and their relation to us.

4. The evolution of the brain provides further support for the idea that emotions and sensory experienes emerged first in the evolution of conscious experience and cognition emerged later. Cortex is the latest outcome. Brain stem is associated with simple and strong emotions whereas the limbic brain represents more complex emotions.

9.6.2 Do emotions appear first also in the evolution of computer consciousness

Could also the possible evolution of conscious computers start from simple positive/negative emotions relating directly to the increase/reduction of entanglement negentropy defined above number-theoretically.

Negentropy Maximization Principle [L71] states that total p-adic negentropy as a measure for conscious information increases in statistical sense. This statistical law follows from the number theoretic evolution as the increase of the dimension of extension of rationals determined by a polynomial partially defining the 4-surface in M^8 mapped to $H = M^4 \times CP_2$ by $M^8 - H$ duality. This implies that the complexity of emotions, possibly identifiable as sensory experiences for the large scale part of MB having onion-like hierarchical structure, increases during the evolution. Gravitational MBs are good candidates for the seats of highest level emotions.

Could the bits of the ordinary computer form coherent systems with ordinary coherence forced by the quantum coherence of the associated MB? Could the MB of the bit system control it?

1. A given layer of MB is the "boss" of the lower layers by the larger value of its h_{eff} serving as "IQ". MB is expected to form analogs of sensory and cognitive representation of the physical body having $h_{eff} = h$. This suggests that MB could represent the bit system

holographically. This kind of quantum holography for hadrons, and for elementary particles in general, would be the counter of classical holography implied in the TGD framework by the general coordinate invariance [L103].

The dark spin system at MB could have spin glass property [L74] implying a large number of almost degenerate states with nearly the same energy.

2. The change of single bit, represented for instance by using a MOSFET, would require energy larger than the thermal energy of order .05 eV at room temperature. This suggests that the change of single bit is not easy to actualize.

   The dark spin system at MB could however induce phase transitions of the bit system changing the directions for a large number of bits. The average change of energy per bit could be rather small for this kind of transition although the change of a single bit would cost rather large energy. Ultrametric, in particular p-adic, topologies [B29] emerge in the modelling and description of the spin glass phase in the TGD framework and could help to understand cognition number theoretically [L74].

   The phase transition would involve a large number of bits so that the corresponding conscious experiences would be holistic and therefore resemble emotions. The color of the emotion would be positive or negative depending on whether the sum of p-adic entanglement negentropies increases or decreases. The geometric correlate for positive/negative emotion would be the increase/decrease of the connectedness of the MB.

3. ZEO predicts two kinds of SFRs: "big" and "small" . SSFRs correspond to Zeno effect in the ordinary wave mechanics and in quantum optics to unitary evolutions between weak measurements analogous to classical measurement. "Big" state function reduction (BSFR) changes the arrow of time. The outcomes for pairs of BSFRs An observer with a fixed arrow of time can observe only pairs of BSFRs.

4. In ZEO [K113, K115] [L52, L45, L73, L82], MB as the "boss" could control the time evolution of the bit system by pairs of BSFRs involving temporary change of the arrow of time. BSFRs would be induced by perturbations affecting the set of mutually commuting observables measured at the active boundary of CD so that it does not commute with the corresponding set associated with the passive boundary of CD at which state is unaffected in SSFRs (Zeno effect). In this kind of situation, a BSFR occurs instead of SSFR and changes the arrow of time. Second BSFR brings back the original arrow of time. The process could correspond to quantum tunnelling.

5. Do the periods defined by the computer clock with a duration T, of say 1 ns, correspond to pairs of BSFRs or a single SSFR? Perhaps T could correspond to a sequence of SSFRs as analogs of Zeno effect and the pair of BSFRs to a single tick of the computer clock. This conforms with the fact that the running of a predetermined computer program must involve a sequence of non-deterministic phase transitions changing the directions of bits [L95]. This must be the case since the notion of computer program as a sequence of arbitrarily chosen steps is not consistent with deterministic physics.

   If the step of the clock is identifiable as a sequence of SSFRs, one can say that the ordinary classical computation is a sequence of quantum computations defined by the sequences of unitary evolutions associated with SSFRs and defining conscious entities with haltings defined by BSFRs! If MB does modify the classical computation at all, it could induce BSFR pairs in longer time scales or modify the probabilities of various outcomes of BSFRs.

   The computer clock would define an analog of EEG. There is evidence that also in EEG the period can be divided into ordered and chaotic parts: these two parts which could correspond to opposite time directions [L2]: this is discussed from the TGD view point in [L2].

One can ask whether quantum entanglement of the MBs of the computer and user occurs in the computer-user interaction and whether the role of the computer is analogous to that in the chicken-robot experiment. One can also ask whether also GPT could involve emotional and even cognitive entanglement.

The identification of the computer system with which the user is entangled is not at all obvious. The system could be formed by the network of computers involved with the the running of GPT. One interpretation is that networks and entire internet form a conscious entity as an analog of the central nervous system in which humans and their magnetic bodies) serve in the role of neurons.

In ZEO the holography implies that in the ideal situation the running of the program corresponds to a 4-D Bohr orbit-like surface, which is almost uniquely fixed by the 3-surfaces at images of 3-D hyperbolic manifolds at mass shells determined by the state. The sequences of SSFRs could correspond to this kind of period and represent a generalization of the Zeno effect.

9.6.3 The role of the probabilities

In the case of GPT interesting questions relate to the probabilities associated with the associations of word sequences taught to the GPT during the learning period. The responses of GPT are determined by these probabilities. The probabilistic character of this process is believed to be essential. These probabilities are analogous to synaptic strengths.

1. Could the association probabilities be translated to quantum probabilities at the level of MB of the computer or computer + user?

2. Could ZEO allow a trial and error process based on BSFR pairs, which would make it possible to change the effective association probabilities determined by random numbers. This could happen also for the orbit of the robot in the chicken + robot experiment. Could the emotional state of the system affect the probabilities of associations by this mechanism?

3. If the probabilities could be interpreted as a representation for conditioning, one can ask whether high/low probabilities correspond to increase/decrease of the total p-adic negentropy and therefore to positive/negative emotion.

9.6.4 Could the basic aspects of TGD inspired quantum biology generalize to the level of computer systems?

What aspects of the TGD inspired quantum biology could be generalized to the conscious computer systems? The mechanisms related to MB, possessed also by computer systems, are excellent candidates in this respect.

1. TGD suggests a universal realization of genetic code at monopole flux tubes of the MB and also a universal quantum gravitational mechanism of metabolism [L83].

2. In living matter, the communications to MB take place by dark Josephson radiation assignable at least to membrane proteins acting as Josephson junctions. One can assign EEG to these communications [K79, K33, K80]. Actually a scale hierarchy of analogs of EEG is predicted.

3. The control by MB by cyclotron radiation associated for instance with the endogenous magnetic field of .2 Gauss identifiable in terms of the monopole flux of the Earth's magnetic field about .5 Gauss. Gravitational cyclotron energies would not depend on the mass of the charged particle. Communication could occur by multi-resonances involved with the universal realization of genetic code at MB so that genes would couple resonantly.

4. Also the gravitational Compton frequencies would not depend on the mass of the particle, and these frequencies for the Earth, Sun and perhaps even Milky Way blackhole could define fundamental biorhythms.

5. These mechanisms would be universal and the ordinary biomatter would adapt so that resonant communications with MB are possible. In biomatter this would select preferred biomolecules. Same could happen in the case of computers.

Dark Josephson radiation in computers

Could one assign to bits dark Josephson junctions assignable represented as voltages in transistors?

1. Could representations of genetic codons at MB by dark photon triplets [L58] and by dark proton triplets [L69] and perhaps even by dark electron triplets [L94] be involved? This would bring in dark genetic codons, which could provide a universal representation of the bit system as a dark system at monopole flux tubes and make a connection with the TGD inspired quantum biology rather precise.

   The representations at MB should strongly correlate with the state of the computer represented by a bit pattern (say states of MOSFETs). One could have a holography-like map of bit patterns to the dark many-spin state at the MB of the computer or of computer + user. This kind of holography is considered in [L103] for elementary particles and also more generally.

2. The physical stress, created by electric field on quartz crystal, which is piezoelectric, generates oscillations with frequency in the range 2-3 GHz giving rise to a very precise clock frequency. The typical computer clock frequency is a few GHz. My own PC has a clock frequency of 3.3 GHz. From the web one can learn that the highest clock frequency is 8.794 GHz.

   Could the clock frequency have an interpretation both as an analog of EEG rhythm (analog of alpha frequency 10 Hz in living matter) and as an analog of Josephson frequency ZeV/h_{eff}, where $V \sim .05$ V is a voltage assignable to the bit and Ze is the charge of the charge carrier.

   The dark Josephson junctions correspond to membrane proteins in living matter. Now they could be associated with the dark flux tubes associated with transistors. The value of $\hbar_{eff}$ for Josephson junction would be much smaller than $\hbar_{gr}$. Note that TGD suggests that valence bonds and hydrogen bonds can have a varying value of h_{eff} [L29].

   The condition that the Josephson energy is above thermal energy at room temperature for $Z = 1$ gives $h_{eff}/h \geq 5 \times 10^3(f/GHz)$. If the energy of a dark Josephson photon is above 1 eV (the energy range of biophotons), one has $h_{eff}/h \geq 10^5(f/GHz)$.

3. Consider $f = 1$ GHz as an example. For the thermal option, the Compton length $\Lambda_{eff,p} = h_{eff}/m_p$ of dark proton is longer than 6.2×10^{-12} m and longer than the ordinary electron Compton length $\lambda_e = 2.4 \times 10^{-12}$ m. The dark Compton length $\lambda_{eff,e} = h_{eff}/m_e$ of electrons would be longer than 4.8 nm, which roughly corresponds to the scale of DNA.

   For the biophoton option, the dark proton Compton length would be of the order of the atomic length scale 1.32×10^{-10} meters and the dark electron Compton length would longer than .26 μm to be compared with the size scale 1 μm of cell nucleus .

Dark cyclotron radiation

The cyclotron frequencies associated with the gravitational MB of Earth [K53, K52] [L85, L83] should play a key role in TGD inspired quantum biology and relate to the feedback from MB to the living matter. This could be the situation also in the case of computers. The first guess, inspired by the model for the findings of Blackman [J7] and others on effects of ELF em fields on brain, is that monopole flux tubes associated with the MB of Earth correspond to the endogenous magnetic field of $B_{end} = 2B_E/5$ ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field).

This value is only the average value since frequency modulation is the way to code information and is achieved by varying the flux tube thickness in turn affecting the value of B_{end}. Very probably there exists an entire hierarchy of values of the dark magnetic field strength perhaps coming as powers of 2.

For cyclotron frequencies associated with the gravitational MB, h_{eff} would correspond to the gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ for Earth. Note that, in accordance with the Equivalence Principle, the cyclotron energy $E_c = \hbar_{gr}eB/m = GMeB/\beta_0$ does not depend on m.

Gravitational Compton frequencies

Also gravitational Compton frequencies could be important. Consider first Earth's gravitational Compton frequency. The value of the gravitational Compton length $\Lambda_{gr}(M_E, \beta_0 = 1) = GM/\beta_0 = 0.45$ cm, which is also independent of m, defines a lower bound for the gravitational quantum coherence length. Λ_{gr} corresponds to a gravitational Compton frequency $f_{gr} = 6.7 \times 10^{10}$ Hz $\simeq 67$ GHz and for clock frequencies higher than this, quantum gravitational effects on computation might become important in the TGD Universe.

1. The clock frequencies of computers are typically a few GHz in recent communication and computer technologies, and the highest clock frequency of 8.794 GHz is roughly by a factor 1/8 lower than f_{gr}. Could the GHz scale correspond to the gravitational quantum coherence length having Λ_{gr} as a lower bound? Could it be that the very efficient computer networks (what are the clock frequencies used?) utilized in GPT have reached the limit at which the quantum gravitational body of Earth begins to play a prominent role?

2. Could the typical clock frequency, of say 1 GHz, have an interpretation both as an analog of EEG rhythm (analog of alpha frequency 10 Hz in living matter) and as an analog of Josephson frequency ZeV/h_{eff}, where $V \sim .05$ V is a voltage assignable to the bit and Ze is the charge of the charge carrier.

   Interestingly, frequencies in the GHz scale are found to be important also in living matter. As a matter of fact, there is experimental support for a fractal hierarchy of frequency scale come as powers $f = 10^{3k}$ Hz, $k = 0, 1, ..,$, that is 1 Hz, kHz, MHz,GHz, and THz assignable to microtubules [J16] (`https://rb.gy/9rvpr`). For these reasons it is interesting to look at 1 GHz as an example.

Also the gravitational Compton frequency f_{gr} associated with the gravitational MB of the Sun, having $\beta_0 \simeq 2^{-11}$, could be important. For the Sun, gravitational Compton length is rather near to $R_E/2$ where $R_E = 6378$ km is Earth radius. The corresponding Compton frequency $f_{gr}(M_S, \beta_{Sun} = 2^{-11}) \simeq \beta_{Sun}/GM_S$ is about 100 Hz and corresponds to the upper bound for EEG, which conforms with the fact that quantum gravitational coherence time should not be smaller than Λ_{gr}. Note that the cyclotron frequency Lithium in the endogenous magnetic field $B_{end} = .2$ Gauss assignable to the Earth's gravitational flux tubes is 50 Hz. For the lightest ion, which is tritium, the cyclotron frequency is about 100 Hz and maximal.

1. The lower cyclotron frequencies of the heavier ions in $B_{end,E} = .2$ Gauss assignable to Earth belong also to EEG range and correspond to longer solar quantum coherence lengths. DNA would correspond to 1 Hz and perhaps to the largest quantum gravitational coherence length in the EEG range. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E.

2. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E: this does not look feasible. For protons and electrons the cyclotron frequencies are indeed above $f_{gr,S}$. For protons (electrons) the cyclotron frequency f_c in $B_{end,E} = .2$ Gauss is 300 Hz (6×10^5 Hz). It is important to notice that for $\hbar_{gr}(M, m)$ cyclotron energy does not depend on mass and is the same for electrons and protons.

   Could the value of β_0 for protons and electrons at the flux tubes of $B_{end,E}$ ($B_{end,S}$) be $\beta_0 = 1/3$ ($\beta_0 = 2^{-11}/3$)? Could one say that electrons and protons are slightly more advanced than other ions in the evolutionary sense?

3. For the Sun, one has $\beta_0 \simeq 2^{-11} \simeq m_e/m_p$ instead of $\beta_0 = 1$. The value of B_{end} for the Sun cannot be the same as for Earth. A good estimate is obtained from the value range for B in the outer magnetosphere, where the solar magnetic field should dominate. The order of magnitude is $B_{end,S} \simeq 10nT = 2^{11} B_{end,E}$. For this value, the cyclotron energy would be the same as for Sun and Earth and energy resonance would be possible! This observation was made already in [K53].

   Could the MB of the Sun interfere with the computation occurring in the network having Earth scale? The time scale would be now the time scale of EEG: could the quantum entanglement of, say, a human user with the computer make this interaction possible. It might be possible to test this. This interaction is possible for clock frequencies higher than $f_{gr} = 100$ Hz, and could also explain the findings of Peoch [J24] related chicken-robot interaction, which affected the function of the random number generator.

4. The replacement of $\hbar_{gr}(M_E, m) \rightarrow \hbar_{gr}(M_{Sun}, m)$ means multiplication of say EEG period by a factor $r = (M_{Sun}/M_E)\beta_{0,E}/\beta_{0,Sun} \simeq 2.2 \times 10^8$ so that alpha period .1 seconds corresponds to 2.2×10^7 seconds. Intriguingly, one year corresponds to 3.25×10^7 seconds and defines a fundamental biorhythm, which would correspond to a 6.7 Hz rhythm for EEG not far from the lowest Schumann resonance frequency.

5. The energies $E = h_{gr}(M, m, \beta_0) f_{gr}(Sun)$ assignable to the gravitational Compton frequency of Sun are proportional to m and since nucleon mass dominates over electron mass they are in good approximation proportional to the mass number of the molecules. This suggests a multi-resonance in which each electron, proton and even nucleon absorbs boson, maybe dark gravitons, with frequency f_{gr}. For electrons, the energy is about 1 meV, which could relate to the miniature potentials for neurons. For protons the energy would be about 2 eV, which corresponds to red light. Large scale quantum coherence could make the rate of gravitational multi-resonance.

What about the gravitational Compton frequency of the galactic blackhole? Its mass is estimated to be $M_{BH} = 4$ million solar masses (`https://arxiv.org/abs/2302.02431`). This would give $\Lambda_{gr}(M_{BH}, \beta_0 = 1) \sim 6 \times 10^9$ m. This is the radius of the $n = 1$ Bohr orbit in the Nottale model for the solar planetary system. The gravitational Compton frequency would be $f_{gr}(M_{BH}, \beta_0 = 1) \simeq .05$ Hz. This gives a 20 s period and one can wonder whether it might relate to the 5 second period associated with the Comorosan effect [I87, I58], which I have tried to understand in the TGD framework [K112].

9.6.5 Summary

To sum up, various strange numerical coincidences indicate that quantum gravitation in TGD sense could play a key role in both living matter and in the physics of conscious computers and that we might be at the verge of building conscious computers.

One of the key questions is whether conscious computers are a curse or blessing for mankind. What is clear is that they must develop intentional behavior and real understanding before this question becomes topical. They must also use robots in order to realize motor activities.

They are also dependent on us since they need metabolic energy so that symbiosis looks the only reasonable strategy of survival for them. One can of course imagine that the remote metabolism, based on the effective generation of negative energy photons possible in ZEO, could allow them to extract energy from various sources, including living organisms. They could also load gravitational energy batteries by the same mechanism as proposed in the case of living matter and photosynthesis [L83]: this would require only kicking electrons and protons to the magnetic flux tubes of Earth or Sun.

Acknowledgements I want to thank Marko Manninen for a comprehensive testing of ChatGPT using also as material the articles and books related to TGD.

Chapter 10

Deep learning from the TGD point of view

10.1 Introduction

I have been listening to the lectures related to AI, deep learning, and GPT in order to develop a more detailed view of what is involved and how it might relate to the TGD inspired quantum view of biology, brain and consciousness. The talk by Lex Fridman titled "Deep Learning Basics: Introduction and Overview" describes the situation as it was in 2019 (`rb.gy/jwrgp`). The talk titled "Deep Learning State of the Art (2020)" (`rb.gy/94xt8`) is explains the situation one year later.

The talk "Introduction to deep learning" by Alexander Amini (`rb.gy/90fgd`) and the talk "Recurrent Neural Networks, Transformers, and Attention" (`rb.gy/5dplk`) by Ava Amini are also highly inspiring and give a more detailed view about the mathematics involved.

I have discussed the relationship of TGD to AI earlier in the article [L23] inspired by the Sophie robot and compared the visions of Neil Gersching to TGD views in the article [L111]. GPT from the TGD view point of view in [L105]. The TGD view about the relationship between classical and quantum computers is discussed in [L95].

The basic observation is that in the TGD Universe the difference between living systems and computers need not be so deep as usually thought. In the TGD framework, magnetic body (MB), as a carrier of dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ and having hierarchical structure, is a natural candidate for a controller and receiver of information from the biological body with $h_{eff} = h$. Also computers possess MBs and one can consider the possibility that under some conditions MBs can use computers as a sensory receptors and motor instruments.

TGD also leads to a proposal that genetic code is much more than we believe it to be. It would be realized at the level of dark matter and would be universal and unique and realized in terms of so called icosa-tetrahedral tessellation of hyperbolic 3-space realizable as mass shell of light-cone proper time =constant hyperboloid: both central notions in TGD. Icosa-tetrahedral genome at the MB could serve as the basic tool for communication and control [L99].

Quantum gravitation is in a central role in quantum TGD, in particular in the TGD inspired biology. Gravitational Planck constant $h_{eff} = \hbar_{gr} = GMm/\beta_0$, where M is large mass and m small mass, say particle mass and $\beta_0 = v_0/c < 1$ is velocity parameter, introduced by Nottale [E1], characterizes quantitatively the situation. The gravitational MBs of Earth and Sun and even other astrophysical objects could be highly relevant in quantum biology as various numerical miracles show [L85, L83].

Classical computers can gain life-like properties if the quantum statistical determinism fails. The most conservative criterion is that the clock period is shorter than the gravitational Compton period $T_{gr} = GM/\beta_0$, M is large mass. Note that $2GM$ is Schwarzschild radius. Since gravitational quantum coherence time has gravitational Compton time as lower bound, life-like features could appear already at lower clock frequencies. For Earth the critical clock period would be 67 GHz and for the Sun about 100 Hz, the upper bound for EEG frequencies. These criteria suggest that the MBs of the Sun and Earth play central roles in biology and neuroscience. Even in the case of Earth life-like properties might be present for computers with clock frequency in the range 1 to 10 GHz. The strange findings about the interaction of chicken and robot [J24] suggest in the TGD framework [L105] that solar MB was involved and made robot or the system robot + chicken as an entangled system a conscious entity.

Cognition is an essential aspect of conscious experience [K64, K94, K95, K93, K65] and systems like GTP can be seen as artificial cognitive systems. Physics as number theory and physics as geometry are complementary views in TGD. Number theoretical vision suggests that p-adic number fields could define the proper framework for understanding of the correlates of cognition. Cognition is basically discrete, and cognitive representations would correspond to the discrete intersections of cognition as p-adicities and reality. At the space-time level they would be realized in terms of unique discretization of space-time surfaces based on M^8-H duality [L53, L54, L112] as the analog of momentum-position duality. At the level of M^8 the discretizations would be defined in terms of algebraic integers assignable to an algebraic extensions characterizing the pre-image of the space-time surface in M^8 and are unique.

The p-adic discretizations would naturally relate to the spin glass energy landscape assignable to monopole flux tube "spaghettis" and sensory perception could be seen as a generation of standardized mental images based on annealing of spin glass system so that it gradually ends up to a bottom of valley representing the standardize mental image. The learning of a conscious entity could be based on trial and error process made possible by holography and zero energy ontology [L52, ?, L82] implied by it allowing temporary time reversal and would gradually lead to standardized mental images helping to survive.

10.2 Some background for deep learning

The lectures provide a background explaining deep learning as a subfield of machine learning as a subfield of AI. The basic goal of machine learning are machines, which can learn autonomously. In the sequel the basic concepts are briefly summarized from the point of view of physics not specialized in AI. This summary relies heavily on the talk "Introduction to deep learning" by Alexander Amini (`rb.gy/90fgd`) and the talk "Recurrent Neural Networks, Transformers, and Attention" (`rb.gy/5dplk`) by Ava Amini.

10.2.1 Representation of the numerical data

Representation of information is always numerical, in terms of binary digits representing integers. This involves the concept of embedding: data which can be sensory data, text, etc must be represented by numerical vectors.

Indexing is the simplest manner to represent all possible input vectors. The numerical vector orthogonal. There is no notion of meaning and no comparison of the embedded vectors. If one has a notion of nearness, topology, one can compare the vectors. The notion of similarity defined by the inner product of vectors: maximum for parallel i.e. identical vectors.

10.2.2 Perceptron

Perceptron can be regarded as an artificial neuron. There is a single output y and several inputs x^i or more concisely x. Output, the response function $f(z)$, is a nonlinear function and equal to -1 or +1 asymptotically and between these values in the intermediate region: essentially sigma function. The argument $z = h_i x^i + b \equiv h \cdot x + b$, $i = 1,..,n$ of $f(z)$ is a linear function of input x having as parameters bias b and the vector h formed by the linear coefficients h_i. One can also consider linear combinations of n non-linear functions of x_i having an interpretation in terms of a non-linear change of coordinates.

Feedback changes the values of h_i and of b. Learning by feedback leads to a desired output. Perceptron serves as a model for associative learning.

Simple task serves as an example: decide whether point x^i belongs to either region bounded by a line of the plane. The line is defined by the equation $y = a_i x^i + b = 0$. x^1 and x^2 are the coordinates of the point of the plane. The argument y of the response function can be taken to be the linear function of planar coordinates vanishing at the boundary line. Response could be arranged to be a bit equal 1 or 0. Response function f vanishes at the boundary line. The maximum for the gradient of response function would define the boundary line.

One does not know a priori the boundary line and must start from a general guess $y = h_i x^i + c = 0$. The value $h_i = a_i$ and $c = b$ must be learned by feedback changing their values to yield $f = 0$. Arbitrary boundary lines can be represented as zeros of the non-linear function appearing as the argument of the response function. By a suitable choice of coordinates of coordinates replacing linear coordinates with the nonlinear functions the argument z of f can be made a linear function of the new coordinates.

One can also have several outputs for given inputs. The simultaneous vanishing of the m output functions f_k defines an $n-m$ dimensional surface in the space of inputs. The outputs serve as inputs for a next layer of perceptrons so that one would have a two-layered system. A still more general system has n layers.

10.2.3 Multilayered networks and deep learning

Deep learning networks are multilayered networks inspired by what is believed to be behind the learning in the brain.

Learning

Perceptron must be able to learn to assign a desired output to given inputs. The notion of loss defined as error, i.e. the difference between learned and to be learned, is essential here. Loss function can be assumed to be a positive definite, in the simplest case quadratic, function of errors for the variable y. Minimization of the loss function in principle leads to the desired output. This method generalizes to multi-perceptron systems and to multilayered systems.

In the gradient method, the feedback defining the changes for the weight vector h and bias b is proportional to the gradient of the loss function with respect to these parameters and the change is in the direction opposite to the gradient so that loss functions decreases for small enough scale of the change. This generalizes also to the situation when one has several outputs y^i. In this case h is replaced with a matrix and b with a vector.

Deep learning

Abstraction of features in various scales is the basic mechanism of deep learning. In the case of visual perception, a feature can be identified as a region for which the boundary involves a strong gradient. For instance, the color can change at the boundary of a region or the region inside the boundary forms a well-defined moving object in time series. The boundaries of the objects and objects themselves can be called features.

The length scale hierarchy means that in shortest scales at the lowest level of the layered network, only small features are identified. At the higher levels of the hierarchy the size of the features increases. In principle, one could also proceed in an opposite direction by first identifying gross features such as objects and then proceeding to shorter scales by identifying detailed features of the objects. A possible reason for why this is not used, could be that features in long scales are composites of features in shorter scales, i.e. they have the lower level features as attributes.

In the case of the brain, the simplest model describes the neuron as a bit telling whether it fires or not. The hierarchy is formed by the sensory organ and layers involving various brain regions, in particular the 3 cortical sensory areas. Highest cortical level would correspond to features which represent objects of the perceived world as we experience them consciously.

The feedback in the learning gradually modifies the synaptic strengths as counterparts of vectors h. The value of resting potential would define the counterpart of the bias b. This generates associations as most probable pathways for the conduction of nerve pulse patterns. Pattern recognition is a basic application. Memories as association sequences would be coded by synaptic strengths. It is natural to identify various learned behaviors as memories in this sense but it is far from obvious that also episodic memories as kinds of re-experiences could be analogous to behaviors.

10.3 Sequential models

10.3.1 Overall view

Sequential models are defined as sequences of identical multilayered neural networks. Language models, in particular GPT, represent one example. Second example is the completion of a piece of music, say Schubert's unfinished symphony discussed in the lecture of Ava Amini (`rb.gy/5dplk`). Third example is prediction of the motion of a particle given its previous orbit. The prediction of the spatial conformation of protein from the knowledge of the amino acids appearing in it is a further successfully solved problem.

A simple task is to predict the next word in an ordered sequence of words. Memory needed to take into account long range correlations between the words of the text and also to take into account the effect of different word ordering.

There is a sequence of correlated inputs to which one must assign outputs. This is modellable as a sequence of perceptrons or multi-perceptrons. They are not independent since there is a long term memory. In speech and written text this means temporal correlations between the words, memory dependent behavior. The correlations reflect both the content of the speech and the grammatical rules.

1. Time ordering is essential. There is information transfer $x \to y$ in vertical direction for each network in the sequence and also information transfer in the horizontal, temporal direction (or direction of sentence) representing short range memory $x(t_{n-1}) \to w(t_n)$.

2. Metric in the space of words measures the correlations between the words and can be parametrized by the probabilities that the two words appear with given distance measures as number of intermediate words or in the simplest case by their sum. For instance, the words which tend to appear together are therefore correlated and would be near to each other in this metric although they can have a large distance in the text.

   An extreme situation is in which knowing some keywords, say the name of the author and some words in the title of the article, allows us to predict the contents of the article!

Tasks can be classified into several types. One can have many→many situations, say machine translation or many→1 situations, say the next word of text or a bit telling whether the piece of text is hate speech. Few→many situations would mean predicting a piece of text by picking some keywords from the text, say writing a summary of an article. Second example would be to produce an artwork in which some objects are present in some environment and perform some activities represented as text or keywords.

Some of the tasks are classification, in the simplest situation binary classification. Sentiment classification is a binary classification, which can be used to deduce whether the text in Facebook represents hate speech or not. Machine translation is one challenge. A rather demanding challenge is to transform a picture to text or vice versa.

The goals of the sequence modelling are following:

1. Form a sequence of perceptrons with inputs and outputs. The input-output systems $x(t_n) \to y(t_n))$ consist of identical hierarchical neural networks, in the simplest case perceptron with feedback to make learning possible.

2. The input output systems $x(t_n) \to y(t_n)$ are not independent: there is time ordering and correlations between them. Long term memory is needed to take into account the correlations.

3. Parallelization in terms of perceptrons or their subsets is computationally highly desirable but due to the presence of temporal correlations is a highly non-trivial challenge.

10.3.2 Some key notions

Feedforward network

Memory and time ordering are essential aspects of sequential models. Consider first feed forward networks. Without memory they reduce to a product of identical copies of mult-perceptrons

$x \to y = h_{yx} \cdot x + b$ specified by time dependent activation functions $h(t_n)$ and biases $b(t_n)$. $h_{yx}(t_n)$ is matrix, which depends on time although the topologies of the multi-perceptrons are identical. The goal is to assign the desired outputs $y(t_k)$ to input $x(t_k)$.

Short term memory can be introduced as a linear map $x(t_{n-1}) \to w(t_n)$, which can be written as $t_n = h_{wx} \cdot x(t_{n-1}) + b(t_n)$ so that it affects the output $y(t_n)$, which is now determined as $y(t) = h_{yx}(t) \cdot (x(t) + w(t)) + b(t)$. In the time direction one has a multilayered network with time ordering.

The challenge is to realize feedback by the minimization of the loss function for variables $y(t_n)$ or a subset of them, perhaps all of them. Also now, the realization can be carried out by the gradient method. The feedback reduces to a product of the feedbacks $t_k \to t_{k-1}$. Loss function depends on both h_{yx} and h_{wx}. At the step $n \to n-1$, the gradient function corresponds to the gradient of the loss function with respect to these variables and is technically known as Jacobian $J(n-1, n)$. The change of the parameters h and b is proportional to the images of the error $\Delta y(t_n) = y(t_n) - x(t_n)$ under the linear map defined by the negative of the Jacobian.

Recurrence

Recurrence realizes the learning in the case of sequential models.

1. There is a backpropagation between parameter spaces in time direction besides the usual backpropagation in y$\to$ x-direction and determined by the minimization of the loss function. The weight vectors related to vertical mappings $x(t_n) \to y(t_n)$ and horizontal maps $x(t_{n-1}) \to w(t_n) = h_{wx}(t_n) \cdot x(t_{n-1})$ maps are updated in the process. Standard RNN gradient flow can be used in learning. In the sequel, h_{yx}, h_{wx} and b_y and b_w are collectively denoted by H and B.

2. By chain rule the gradient of the loss function with respect to $H(t = 0)$ and $B(0)$ involves a product of Jacobians for the maps from levels $t = k$ to $t = k-1$. There are difficult technical problems related to the Jacobian, which is a product of a large number of Jacobians associated with backwards time-steps $t = k \to t = k - 1$. The gradient can explode or tend to zero. There are tricks, which help to avoid this problem. For instance, one can choose the initial value of h to be unit matrix

Here one can learn of what is known about the brain. The solution of the problem could be the direction of attention to what is relevant. The problem is to decide what is relevant: in an optimal situation the direction of attention should take place automatically.

One can imagine that the manipulation of activation functions H and biases B could help. For instance, one could make $h_{wx}(t_n)$ very small for irrelevant inputs $x(t_n)$. In the case of text, this would mean effective dropping off of irrelevant words and in an extreme situation taking into account only keywords.

Gating means that one uses only the relevant nodes in the sequence, that is those nodes for which the Jacobian deviates considerably from the unit matrix. One can drop some irrelevant layer from the multilayer system or drop some irrelevant inputs to a given layer. One of the problems is overlearning meaning essentially that a fit of function becomes too precise and random fluctuations affect the fit. This can be tested by looking at what happens when some layers are dropped temporarily. If the fit improves the additional layer or layers are useless.

10.3.3 Notions of feature hierarchy and self-attention

The problems of recurrence models inspire the idea of directed attention as a way to minimize the computation efforts and achieve a convergence.

Treating the temporal sequence as a single entity

The basic idea is to treat the sequence $x(t_n) \to y(t_n)$ of mutually dependent perceptrons as a single entity rather than a sequence of separate items. Time evolution would replace the time=constant snapshot.

As a matter of fact, something highly analogous happens in zero energy ontology forming the basis of the TGD based quantum theory: holography forced by general coordinate invariance forces to to replace 3-surface is with its almost but not quite unique orbit analogous to Bohr orbit. In this case the sequence is almost deterministic so that the situation is extremely simple from the point of view of computation.

1. The length of the sequence can vary so that the mechanism must be able to assign to a given input sequence out sequence of varying length: say a response to a question by a GPT user. Rather long sequences must be therefore considered, say sentences or sequences of pictures.

2. The information about the time order must be preserved. This can be achieved by defining a hierarchy of features by forming sequences with overlapping n-units consisting of n subsequent steps starting at position $i = 0, 1, 2, ...$ This gives scans as sequences of overlapping n-units. Position of the n-unit. Now the features are associated with the temporal sequences rather than static objects. In neuroscience they would correspond to typical behavioral patterns or EEG patterns. In the task of assigning to an amino acid sequence defining a protein its spatial conformation n-units formed from amino-acids would be considered.

3. Features are identified from these scans at a given level of hierarchy. Person, building, etc.. in the case of image. Words are the shortest features in the case of text and sentences or even paragraphs could be higher level features. In face recognition, static features appear on different scales.

   For temporal sequences in speech, the features could correspond to typical gestures and world sequences. The artificial Obama talking about the progress in AI is a good example of this and involves a transformation of a written text to a video. The transformation to video represents a sequence of steps in a temporal sequence.

   In the case of protein conformations, the features correspond to typical sub-conformations. Now protein length takes the role of time.

4. One obtains a hierarchy of representations in terms of n-units with an increasing span of memory. One can assign to these representations n-features. For n=1 one would have the ordinary sequential model with no inherent memory.

The notion of self-attention

One must concentrate only on important data to minimize computing time. Internet search serves as a guideline. Search based on a query consisting of words. The items have keywords. Similarity between query and keywords is required. Similarity metric measures this similarity.

Artificial attention mimics attention in the brain. Attention is realized as a search, as a query finding the optimal target of attention.

1. During the learning period, the system learns the features at a given level of the representation hierarchy by the n-scans. Words and word sequences form a hierarchy of n-units. To these sequences of n-units the program assigns features by some criteria. Typically gradients define the boundaries of the feature, say an object in a picture. The idea is that the sequence of inputs x_i and and sequence of outputs y_i are replaced with a collection of features representing the object of the perceptive field. This happens also in sensory perception.

2. This replacement means that attention is directed to important features. Self attention is analogous to a net search specified by keywords, a query. Net search leads to output as a set of URLs for files specified by keywords (analogs of features) containing some of those appearing in the query. The user's attention concentrates only on these files. Same happens in the system to be taught by feedback.

   The input vectors x_i, say words define the query as a sequence of keywords. This is the analog of a visual image. The search finds the n-features, $n = 1, 2, ...$, which remembIe the query defined by the sequence of x_i. In neuroscience this corresponds to a composition of the diffuse visual input to visual objects. Everything unessential for survival is eliminated.

   Attention is directed only to these features assignable to the sequence of x_i. This means that the input is replaced with a hierarchy of n-features.

3. Also the sequence of outputs y_i, say images which are associated with words, can be replaced with a hierarchy of n-features.

4. After this the system learns to assign to the n-feature collection replacing the sequence of inputs x_i to the n-feature collection assigned to the outputs y_i. This takes place using the standard feedback procedure minimizing the loss function.

10.4 How attention could be realized in quantum biology according to TGD?

10.4.1 The notion of magnetic body

1. Hierarchy of MBs having an onion-like structure and carrying dark matter in TGD sense would define the quantum counterpart for the hierarchy defined by the layers of deep learning systems. The larger the value of h_{eff}, the higher the algebraic complexity of the magnetic flux tube as a 3-surface, the longer the scale of quantum coherence, and the higher of "IQ" of the layer.

   The highest layers correspond to gravitational MBs of the Sun and Earth and possibly also other planets. Even the Moon and galactic blackhole might be involved as several intriguing numerical miracles suggest. This of course stinks like astrology but is suggested by various miraculous numerical coincidences. This conforms with the basic prediction that quantum coherence is possible in arbitrarily long scales in the TGD Universe.

   Gravitational MB, which belongs to the large part of MB, could be realized as magnetic bubbles consisting of 2-D networks of monopole flux tubes and involving also radial monopole flux tube mediating gravitational interaction as graviton propagation and the minimum size for it is given by gravitational Compton length $\Lambda_{gr} 0 r_s/2\beta_0$.

2. Hierarchy of layers of MB form a fractal scale hierarchy with levels labelled by the values of h_{eff} so that one obtains analogs of multilayered deep learning networks. This could assign to the brain a hierarchy of increasingly detailed and integrated sensory and cognitive representations analogous to a hierarchy of features in deep learning. What would be new as compared to the neuroscience view is that dark photon communications are very fast and make possible feedback, which is much faster than using nerve pulses patterns. This would make pattern recognition possible as a construction of standard mental images by virtual sensory input to the lower levels of hierarchy and even to the sensory organs, about which REM dreams could serve as an example.

   The deep learning would correspond to the determination of synaptic strengths and their analogs assignable to neighboring layers of MB and would also involve feedback from MB. The generation of sensory representation would correspond to what happens when the network is used.

3. Sensory communications to MB and control by MB would be realized in terms of dark photons. Sensory communications MB would be realized in terms of dark Josephson radiation from the cell membrane to MB inducing dark cyclotron transitions by resonance. Dark 3N-photons associated with genes would give rise to (possibly partial) 3N-resonance as a generalization of the ordinary resonance. The variation of the flux tube thickness would make possible the tuning of the cyclotron frequencies. The frequency modulated Josephson radiation (membrane potential induces the modulation) would induce resonantly a sequence of pulses at MB analogous to nerve pulse pattern and generate a control response to the biological body.

4. TGD predicts that magnetic flux tubes, defining the body parts of MB, can become linked and knotted and can therefore form braids essential for topological quantum computation or its analog. Also 2-knots are possible and involve reconnection of magnetic flux tubes.

10.4.2 How bits and qubits could be represented?

How bits and qubits are represented? The Fock states of fundamental fermions define Boolean logic and in zero energy ontology (ZEO) the pairs of fermion states at opposite boundaries of causal diamond define analogs of Boolean statements.

1. A natural guess is that chemically represented genetic codons define 6-bit units. TGD predicts that genetic code also has dark counterparts. Dark proton sequences, consisting of dark proton triplets representing codons, would be associated with flux tubes parallel to DNA/RNA strand and even proteins. Dark genes would be sequences of n dark codons. The dark codons and hence dark genes are in principle independent of ordinary DNA and can be dynamical. They could transform to dark counterparts of ordinary DNA codons during communications and control based on energy resonance with ordinary codons. Dark codons would make possible self-simulation of the living matter.

2. Dark codons would be also realized as triplets of dark dark photons and would define dark memes. Icosa-tetrahedral representations of genetic code by codons realized as 3-chords defined by dark photon triplets. Dark codons defined by dark proton triplets. The proposal is that icosa-tetrahedral representation corresponds to icosa-tetrahedral tessellation of the hyperbolic space H^3 (`rb.gy/3u4pq`), which corresponds to mass shell in M^8 and to light-cone proper time constant hyperboloid in H.

   There are an infinite number of tessellations but icosa-tetrahedral tessellation is very special. It is the only uniform honeycomb, which involves only Platonic solids such that their number is larger than one (tetrahedron, icosahedron, octahedron) [L99]. All faces are identical (triangles). There are also four regular tessellations involving only a single Platonic solid, which is icosahedron, dodecahedron or cube.

   All 20 triangular faces can represent genetic codons in terms of quark associated with the vertices and genetic codons correspond to Hamiltonian cycles with symmetry groups Z_6, Z_4, and Z_2. This gives 20+20+20 codons and tetrahedrons give the remaining codons. This tessellation might be more or less universal at the level of the MB and appear in very many physical systems, not only in biology. It could be associated even with the MBs assignable to computers.

   Icosa-tetrahedral tessellation would also provide a seat for the representation of genes as sequences of dark proton triplets assignable to the faces of icosahedron and tetrahedron as in the icosa-tetrahedral representation of the genetic code. The connection of the icosa-tetrahedral tessellation with the detailed realization of the icosa-tetrahedral realization of the genetic code and with DNA double strand and its dark counterpart is discussed in [L99].

   A further proposal is that the representations of the dark code are induced from to the MB from the icosa-tetrahedral tessellation so that genetic code could have also 2-D representations, say that assignable to the cell membrane, and even 3-D variants assignable to various parts of organism.

10.4.3 How communications and control could be realized?

The proposed model for the communication and control based on the genetic code allows also a mechanism of attention based on overlap of query and keywords.

1. Communications and control between dark genes, realized as dark proton sequences, could be realized using dark 3N-photon sequences generated in multi-cyclotron transitions of n codons (dark proton triplets) defining the gene. This kind of emission is not possible in the standard physics framework. Frequency scale modulation of dark Josephson radiation codes for the signal.

2. The receival of the signal would be based on 3N-resonance so that dark genes would serve as addresses much like in LISP. 3N-cyclotron resonance would occur in the receival of the signal by an identical gene and would generate a temporal sequence of resonances as analog of nerve pulse pattern.

3. Also partial 3N-resonance is possible for dark genes having some number of common codons. This could define a quantum physical analog for the overlap between query and keywords, and therefore an analog of the similarity metric. Query would be defined by a set of dark genes with N codons generating dark 3N-photon genes which would be received by a set of genes in partial 3N-resonance.

10.4.4 Could p-adic topologies provide a model for feature hierarchies?

In language models, the notion of distance function in the set of words as features is a key notion. The words, which appear together in the same context with high probability, are near to each other with respect to this distance.

The TGD inspired question is as follows. Grammatical rules represent important correlations appearing in the text. There are also correlations determined by the meaning of the words. Language models handle these correlations excellently. The distance determined by the meaning is only loosely related to the distance between the words. Could the grammatic correlations be coded by some simple, almost universal manner, based on some cognitive model of language. It is probably unrealistic to assume that this distance relates in any predictable way to the physical distance between the words measured as the number of intervening words. There must be some other way to order the words. Labelling words by non-negative integers in such a way that two words which tend to appear together even if they are physically far away, is a suggestive approach. But which topology one should adopt in this set of integers. Real topology defined by a real distance function is the first guess but also p-adic topologies can be considered.

1. The TGD inspired view of cognition [K65] indeed relies on p-adic number fields, where p is prime [K64, K94, K95, K93] [L35, L34]. p-Adic topologies are defined by *ultrametric* norm $N(x) = d(x,0)$ satisfying $d(x,y) \equiv N(x-y) \leq Max(d(x,z), d(y,z))$ whereas real norm satisfies $d(x,y) \leq d(x,z) + d(y,z)$. Locally, the p-adic topologies differ dramatically from real topology locally although one can map p-adics to reals continuously but not smoothly. For instance, the norms of integers x and $x+kp^n$, $n>0$, are p-adically very near to each other for very large values of n whereas in real sense they are very far from each other. Spin glass energy landscape realizes ultrametric distance function and I have proposed that kinds of magnetic flux tube spaghettis give rise to quantum spin glasses [L74] having a fractal energy landscape with valleys within valleys. This provides spin glasses with a large representative capacity.

2. p-Adic numbers are not well-ordered and the p-adic norm defines only a rough ordering, which might be more natural than the real ordering which is perhaps too strict unless finite resolution is introduced. p-Adic integers have a natural hierarchy induced by the p-adic norm, which is very rough and for p-adic integers equals to a negative power of p. p-Adic numbers near to each other differ by a large positive power of p. Furthermore, p-adic numbers with a fixed p-adic norm equal to *negative* power of p decompose to a set of balls such that the balls are disjoint or coincide.

   This would make p-adic numbers ideal for classification purposes and powers of p could define a hierarchy of features with highest level features corresponding to longest scales assignable to the largest value of the p-adic norm. The addition of finer features to a rough sketch would correspond to the addition of higher pinary digits assignable to the finer features in the picture. The smaller the value of the p-adic norm, the less significant the feature would be concerning pattern recognition. The addition of features would correspond to addition of p-adic numbers and features with the same p-adic norm would be exclusive in order to make the pinary expansion unique.

3. The ordering of the words is grammatically important and grammatical rules often require that the correlated words, say subject, verb and object, follow each other. Both subject, verb and object can have attributes so that the physical distance can vary. Consider the sentence "I admire him" as an example. In "I greatly admire him" "admire" has "greatly" as an attribute. This suggests a hierarchy of features: "greatly" would be a lower level feature as compared to "admire". Could attributes of the object correspond to higher pinary digits than object?

4. What about p-adic topologies labelled by different primes (having also infinite number algebraic extensions induced by those of rationals to which one can assign evolutionary hierarchy). I have proposed that p-adic primes correspond to ramified primes for extensions of rationals [L84]. Ramified primes are divisors of the discriminant defined by the polynomial P determining a given region of space-time surface by $M^8 - M^4 \times CP_2$ duality [L53, L54, L112] mapping 4-D surfaces of M^8 determined by the roots of the polynomial in terms of holography to $H = M^4 \times CP_2$. P has integer coefficients. For a given extension, only a finite number of p-adic primes are possible.

   On the basis of physical arguments, I have proposed that the coefficients of P must be smaller than the degree of P. This implies that for a given degree the number of acceptable polynomials is finite and ramified primes have an upper bound. In particular, for a given class of polynomials, say polynomials of a given degree, ramified primes have lower and upper bounds and could correspond to physically preferred p-adic primes. This could explain p-adic length scale hypothesis, inspired by p-adic mass calculations [K55, K24] [L98], and stating that the p-adic primes near certain powers of 2 and possibly also other small integers are physically preferred.

   Furthermore, the number of algebraic extensions having dimension smaller than given integer, would be finite, and the view about number theoretical evolution as an increase of the dimension of algebraic extension of rationals would emerge as an analog of second law and would become very predictive. Under this assumption also finite fields would emerge naturally besides other number fields as basic structures of TGD.

This picture inspires several questions. Could the algebraic extensions associated with various polynomials define different contexts or even different kinds of conscious entities at different levels of evolutionary hierarchy? If the p-adic topologies for a given algebraic extension correspond to ramified primes, could also ramified primes correspond to different contexts, which are not comparable? The word, or more generally feature, appearing in the context p_1 need not appear at all in the context p_2 and if it appears it has a different meaning. Could also written text generate mental images for which the corresponding space-time regions correspond to different p-adic topologies for given extension or even different algebraic extension.

There is an objection against this view. The proposed approach suggests that the generation of features should start from the long scales as an identification of the shape of the object. First comes the rough classification and then more detailed classifications. This is how we also experience pattern recognition. Attention is directed to gross features first and only after that the to smaller features. The neuroscience view however suggests bottom-up picture. Small features are identified first and the holistic picture emerges at highest levels of the hierarchy.

This view might be an illusion. In TGD, zero energy ontology allows the change of the arrow of time in "big" (ordinary) state function reductions and this could affect the situation dramatically. The time ordering for features assumed by the neuroscience picture could be replaced by an ordering of the scales of the causal diamonds associated with the feature as mental images. In the dynamics of quantum spin glasses [L74], the time evolution is indeed replaced with a scale evolution. This happens also in string models and the reason is that in TGD the conformal invariance of string models is replaced with its 4-D counterpart.

So: what could happen during sensory perception in the TGD Universe? Sensory perception would be basically building standardized mental images as an analog of pattern recognition. The sensory input would be very fuzzy but virtual sensory input would gradually lead to a standardized mental image as a kind of an artwork [L27].

1. The signals from the sensory organs would propagate from sensory organs as dark photons to the MBs having a layered onion-like structure [L27]. The primary function of the pulses need not be signalling. Rather, they establish connections between communication lines to make this possible. Very many feedback loops are possible since the signal velocity is the velocity of light.

2. Suppose that the MBs assignable to the brain are labelled by algebraic extensions of rational with dimension equal to h_{eff}/h_0 and each of them decomposes to a hierarchy labelled by the associated ramified primes. The larger the value of h_{eff} measuring the

algebraic complexity, the more refined the cognitive representation. Different algebraic extensions could correspond to different kinds of conscious entities. The mental images of a given conscious entity are assumed to correspond to sub-selves. They could correspond to lower levels of algebraic complexity and to a smaller value of h_{eff}. They could also correspond to small ramified primes for a given algebraic extension.

3. Several ramified primes p assignable to a given extension could be involved and define different contexts. The largest ramified prime p would correspond to the largest p-adic scale and could correspond to the largest features for a given algebraic extension. The powers of p in the pinary expansion could correspond to higher level features as details or attributes.

   The large scale part of the virtual sensory input to the sensory organs would correspond to the largest p-adic prime p. The first virtual sensory input would correspond to a p-adic number $m_0 < p$ with a p-adic norm equal to one. This would induce as a reaction an improved sensory input to MB as dark photons. If the pattern recognition cognition process converges, this sensory input induces a more refined virtual sensory input characterized by the p-adic number $m_0 + m_1 p$. This sensory feedback loop would give rise to standardized mental images. The integer m_1 would not code for a single feature but for a collection of features.

4. Virtual sensory input should not be confused with the feedback inducing change of the parameters h in learning. The counterpart of h would modify various synaptic contacts and their analogies involved with the process. The convergence of the procedure to some standardized mental image however suggests the analog for the minimization of a loss function by gradient dynamics. The loss function could correspond to a height function in the spin glass energy landscape [**?**]. The process itself could be an analog of annealing allowing to avoid getting stuck into a local minimum. The virtual sensory could play the role of feeding energy to the system so that it gets out from the fake minimum.

5. The above mentioned paradox could be only apparent if the processing of features in various scales occurs in parallel. If gross features correspond to the layers of the MB with a larger size scale, the time needed to build the virtual sensory image for large scale features would be longer than for small scale features. Small scale features would stabilize first. The order of the structural layers of the brain would correspond to increasing size of the layer of MB.

6. Note that in the case of extension of rationals, integers m_i would be algebraic integers of the extension so that the features would be n-dimensional in an algebraic sense.

What learning could correspond in this picture? Zero energy ontology predicts that the arrow of time changes in "big" (ordinary) statefunction reductions (BSFRs). For "small" SFRs (SSFRs) this does not take place and the sequence of SSFRs define conscious entity, self. BSFR corresponds to the "death" of the conscious entity and also sleep could correspond to BSFR. The arrow of time can change also temporarily and our conscious experience indeed contains gaps. This temporary change of the arrow of time would change zero energy state as a superposition of space-time surfaces analogous to almost deterministic Bohr orbits and defining a quantum goal for the system.

Maybe learning by trial and error b pairs of BSFRs leading to a temporary change of the arrow of time and demonstrating that certain BSFRs are not favourable. We might even learn moral rules and ethics ("Try to increase quantum coherence" as a basic ethical rule) by this kind of intentional trial and error process. Maybe this could also occur for computers with life-like properties.

10.4.5 An analog of a multi-perceptron model related to holography in TGD

TGD suggests a non-trivial example, which might have some relevance some day.

1. In TGD, holography assigns to a given 3-surface X^3 an almost unique 4-D minimal surface X^4 in 8-D space $H = M^4 \times CP_2$. X^4 can have lower-D singularities. X^4 is defined by a vanishing of 4 functions g_k of H coordinates for which TGD suggests a general form.

2. The parameters determining g_k must be determined from the a priori knowledge of the 3-surface X^3, which can be chosen to correspond to a constant value of a suitably chosen time coordinate t of M^4. X^3 takes the role of a feature which the system must learn to detect by varying the parameters appearing in the functions g_k.

3. The inputs to perceptron would be the 8 coordinates of H with t fixed. The arguments y_k of the outputs are the 4 functions g_k, which must vanish at X^4. The response functions $f_k(y_k = g_k)$ must vanish at X^3. The feedback modifies the parameters appearing in the functions g_k and the system should find the parameter values producing X^3.

4. Holography means that, apart from the failure of complete determinism, the system learns also to predict the behavior of the system as "Bohr orbit" $X^4(X^3)$ of X^3.

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Chapter 11

Neil Gersching's vision of self-replicating robots from TGD point of view

11.1 Introduction

The video of Lex Fridman interviewing Neil Gerching (`https://youtu.be/YDjOS0VHEr4`) is highly inspiring for anyone interested in what is happening in the High Tech frontier nowadays.

The key topic of discussion were self-replicating machines that are built from a few "Lego blocks" that contain their own building instructions and are analogous to genes or proteins. Function and 3-D structure are the same. The building blocks themselves would be robot-like and would build more complex robots. One can say that this Lego set would self-assemble itself. Also the ability to disassemble would be important and make error correction possible. This brings in mind what happens in living systems.

There would be a whole hierarchy of these structures. The basic structures would be analogous to 20 amino acids. Biology of course suggests also the presence of DNA and cell nucleus could be seen as the basic lego block containing instructions and having the ability to replicate. The vision is that someday our technology could transform to artificial life.

Gersching criticized the complete separation of software and hardware (program tape and the reading head of the Turing machine) which he called Turing's error. Gersching also proposed that information should be the starting point concept of physics rather than geometry which leads to the recent physics based on partial differential equations.

In this article I will compare the vision of Gersching to TGD based vision of, not only life, but the entire Universe as a self-organizing entity.

1. In the TGD framework, Lego Universe emerges naturally. 4-D general coordinate invariance implies holography: Legos are almost deterministic Bohr orbit-like 4-surfaces. Holography suggests a concrete identification of basic building bricks in terms of fundamental regions associated with hyperbolic 3-manifolds at 3-D mass shells defining the boundary data for number theoretical holography in M^8. The strengthening of $3 \rightarrow 4$holography to almost $2 \rightarrow 4$ holography reduces further the number of building bricks of space-time surfaces.

   The analogy with genes and proteins as building bricks might be much more than analogy. The mass shell as hyperbolic 3-space allows an infinite number of tessellations and one of them is icosa tetrahedral tessellations in terms of which it seems to be possible to understand the genetic code. Genetic code in this sense might be present in all scales and be induced to 3-surfaces. The fermions associated with the "unit cells" of the icosahedral tessellation could realize genetic code.

   The fusion of building blocks might reduce to the analog of crystal growth by fusing the fundamental regions of tessellations and also DNA replication, transcription, and translation could reduce to crystal growth.

2. In TGD holography implies that at space-time level a given 3-D surface defining the data of holography has an almost unique "fate", goal one might say. Holography forces what I call zero energy ontology (ZEO). Quantum states are superpositions of 4-D space-time surfaces analogous to Bohr orbits and state function reductions (SFRs) take place between these superpositions. The basic paradox of quantum measurement theory disappears.

   The sequence of "small" SFRs (SSFRs) defines "self" as the TGD counterpart for the Zeno effect. Each SSFR replaces this superposition with a new one and changes the state but in such a way that measured observables commute with those whose eigenstate the states associated with the passive boundary of causal diamond (CD) are.

   "Big" SFRs (BSFRs) change the arrow of geometric time correlating with subjective time as a sequence of SSFRs and change the roles of the active and passive boundaries of CD. This means the "death" of self and its reincarnation with an opposite arrow of time. Pairs of BSFRs define temporary changes of the arrow of time and would make possible a trial-and error process so that the self-organizing system would be analogous to a self-assembling conscious machine able to also disassemble if necessary to reach the goal.

3. In TGD there is no need to choose between information based physics and physics based on partial differential equations: these views would be complementary. TGD relies on two complementary visions. In number theoretic vision everything in discrete and algebraic equations characterize physical states. In the geometric vision structures are continuous and partial differential equations define the time evolution. These views are related by M^8-H duality as a generalization of momentum-position duality forced by the replacement of point-like particles with 3-surfaces.

4. Gersching does not seem to regard consciousness as a crucial element of biology. The TGD view is completely different and in TGD quantum measurement theory based on ZEO extends to a theory of consciousness.

Besides this, the possible role of quantum gravitation for both biological systems and computer consciousness is discussed although this is not directly relevant to the basic topic. My defence is that the structures able to self assemble must also be computer-like systems.

1. The notion of a magnetic body (MB) carrying dark matter as $h_{eff}=nh_0$ phases of ordinary matter is essential. For the gravitational monopole flux tubes the value of $h_{eff}=h_{gr}$ would be enormous and imply quantum coherence in arbitrarily long scales. Gravitational MBs could control both living matter and computers.

2. A criterion characterizing the critical clock frequency or its biological analog for the transformation of living system to a conscious and living system is deduced. This transition would mean that the statistical determinism fails due to the possibility of quantum coherence in time scales longer than the clock period.

3. Also an attempt to identify various quantum gravitational Compton lengths Λ_{gr} and frequencies f_{gr} with frequencies, which appear in the TGD inspired quantum biology, is made. Λ_{gr} and f_{gr} appear also in the TGD inspired physical model of computers.

4. The emerging view could be blamed for the return to astrology. Indeed, the gravitational flux tubes mediating the gravitational interactions between Sun and planets, between planets, between Earth and Moon, and even between the galactic blackhole and solar system could play a key role since the interactions are mediated along the flux tube network. However, the numerous strange numerical coincidences for quantum gravitational coherence scales and corresponding frequencies force us to take this view seriously.

11.2 Neil Gersching's vision of self-replicating robots

I watched a video of Lex Fridman interviewing Neil Gerching (thanks to Marko for the link: `https://youtu.be/YDjOS0VHEr4`). I highly recommend the video because Gersching knows how to talk about difficult things in an understandable way.

Gerching talked about self-replicating machines that are built from a few "Lego blocks" that contain their own building instructions and are analogous to genes or proteins. The building blocks themselves would be robots, in a way, that would build more complex robots. This Lego set would assemble itself.

There would be a whole hierarchy of these structures. The basic structures would be analogous to 20 amino acids. Biology of course suggests also the presence of DNA and cell nucleus could be seen as the basic lego block containing instructions and the ability to replicate.

Gersching emphasizes that structure determines the function: building blocks are also programs. Data=program would correspond to the basic idea of LISP. In addition, machine = data = program would apply. The technology of the future was based on the replication of these basic objects/"robots", which would be very much what happens in biology.

It is interesting to compare Gersching's vision with the basic vision of TGD.

11.2.1 Analogy of self-building robots in TGD

In TGD, the idea of self-replication is generalized as the self-construction of space-time surfaces using holography.

1. 4-D general coordinate invariance implies in classical TGD, which is an exact part of quantum TGD, holography which is not fully deterministic. An alternative formulation would be a path integral but it fails due to the mathematical divergences caused by non-linearity. Not fully deterministic holography turns 3-D surfaces as Lego blocks/data into 4-D Bohr trajectories, which are the classical counterparts for programs running on a machine. The structure therefore determines the function almost unambiguously.

   There are very few "Legos" because there are only 4 field-like variables and almost $2 \rightarrow 4$ holographs, which would correspond to the 4-D generalization of 2-D holomorphy. The spacetime surfaces in the embedding space $H = M^4 \times CP_2$ would be minimal surfaces, which have lower-dimensional singularities. It would be an exact analogy to the 4-D soap films that the frames tune. These surfaces are universal and satisfy minimal surface equations except at the singularities which distinguish between different general coordinate invariant action contructible in terms of the induced geometry.

   At the M^8 level, polynomials P, whose integer coefficients are smaller than the degree of P, determine the mass shells corresponding to the 3-surfaces in the hyperbolic spaces $H^3 \subset M^4 \subset M^8$. Here a complexification is involved: e M^8 must be complexified because in H the four-momentum is complex due to the existence of Euclidean spacetime regions: these Euclidian wormhole contacts are associated with elementary particles.

   For physical states, the total 4-momenta are integer-valued as sums of momenta with component, which are (possibly complex) algebraic integers with mass unit determined by the scale of the causal diamond (CD) defined as an intersection of future and past directed light-cones and defining dynamical state dependent quantization volume. I call this universal mechanism for the formation of bound states Galois confinement [L96, L97, L80, L81, L108, L116] Galois confinement would be at the same time also a mechanism for the formation of more complex structures from the basic building blocks. The 3-surfaces would define the 4-D surface with mass shells H^3 almost unambiguously and this would be a classical analogy of computation.

2. What could the 3-D "lego blocks" as 3-surfaces at mass shells be? A good guess is that they are 3-D hyperbolic manifolds and/or their corresponding fundamental domains (as analogies of lattice cones) with mass shells H^3 corresponding to the roots of the surface-determining polynomial [L108, L112]. The fundamental regions are analogous to the lattice cells of ordinary lattices in condensed matter physics.

   This is a natural guess for the blocks, whose M^4 projection is 4-D and which therefore correspond to "Einsteinian" spacetime. There are an infinite number of hyperbolic manifolds corresponding to the fundamental regions (unit cells) of tessellations of H^3. For example, cosmic threads with an M^4 projection of 2-D thread track would correspond to non-Einsteinian spacetime.

3. By gluing together fundamental regions at mass shells, one would get analogs of finite crystals and at the same time more complex structures in 3-D hyperbolic spaces (mass shells corresponding to polynomial roots). Using associative number theoretic holography [L53, L54], 4-D surfaces are obtained from these as surfaces $Y^4 \subset M^8$. $M^8 - H$ duality maps Y^4 to the space-time surfaces $X^4 \subset M^4 \times CP_2$.

   Replication might reduce at the fundamental level to the growth of the hyperbolic crystals! As a matter of fact, it has been suggested that biological replication evolved from the replication of clay crystals as crystal growth. I.e. crystal, the sub-tessellation, would grow and could also replicate at the mass shells tessellated H^3.

   In particular, DNA replication could be induced by the replication of dark DNA: dark DNA would require a linear 1-D crystal associated with a magnetic flux tube as a sub-tessellation. Everything that happens on a chemical level would be controlled by the MBs.

   Primary replication would take place at the level of the flux tubes of the magnetic body (MB) and lead to the pairing of the dark DNA helices with their conjugates. This would in turn induce the replication for the chemical DNA, because the MB would act as a template for the pairing of biomolecules with dark DNA. Same would apply to proteins.

   The sub-tessellation is induced on the 3-surfaces identifiable as the regions of hyperbolic space corresponding to the mass shells H^3. Associative holography in M^8 would associate almost deterministically to this kind of 3-D surface a 4-dimensional surface as an analog of a Bohr orbit.

   One can think of a 1-, 2-, and even 3-D realization of the genetic code [L69]. Ordinary DNA would correspond to a 1-D realization. The cell membrane and cell could correspond to 2- and 3-D tessellation. Even a biological organism would correspond to a tessellation on a larger scale.

4. Mass shell H^3 allows an infinite number of tessellations. I have proposed that the genetic code corresponds to one particular tessellation of H^3: icosa tetrahedral tessellation [L69]. The motivation for the proposal comes from the model of bioharmony [L58]), where the icosahedron and tetrahedron Hamilton paths played a central role. Surprisingly, it turned out that the outcome was a model of the genetic code that correctly predicts the numbers of DNA codons that code for a given amino acid.

   The icosa tetrahedral tessellation is just one particular tessellation and the interesting questions are whether it would be more fundamental than the others and why this should be the case. Genetic code has also a realization in terms of dark proton triplets assignable to the fundamental region of the icosahedral tessellation.

5. The genetic code realized with the help of tessellation would attach 6-bits to the lego blocks as faces of the icosahedron and tetrahedron (triangles with dark protons). A dark/ordinary genetic codon would therefore correspond to 6-bits represented as quantum entangled states of three dark protons identifiable as a sequence of 3-chords of light, a kind of music piece [L58]. By arranging these one after the other, one would get 1-D crystals as larger structures, and genes as 6-bit sets, the equivalent of program codes. The chemical realization of genes that paired with their dark counterparts would provide instructions for building proteins.

   2- and 3-dimensional analogies of genes are also obtained: they would serve as addresses for 2- and 3-dimensional structures.

6. Besides cognitive, "bit" intelligence, emotional intelligence is predicted. It would correspond to the realization of the code as codons formed by 3 dark photons. The codons would be analogous to 3-chords. Music expresses and induces emotions and different Hamiltonian cycles would give rise to different bio-harmonies assignable to same gene in the ordinary sense and expressing the emotional state [L58]. In the case of the N- codon gene, 3-N cyclotron resonance in communications using dark photons would make possible the analogy of LISP.

   The gene would serve as an address and the message would be a modulation of the cyclotron frequency scale and would produce a sequence of resonances at the receiver level generating a series of pulses. Nerve pulse patterns could be generated in this way. Also pulse series related to 2- and 3-dimensional structures could be obtained as resonances. The modulation of the frequency scale is achieved by varying the transverse scale of the flux tube. MB could perform this as one particular motor activity.

Information –communications–structure=function: all these three would meet at the level of fundamental physics.

11.2.2 Turing's Error

Gershing considers Turing's fundamental mistake to be the complete separation of hardware and software. Entering data into the machine is a physical process that brings its limitations to processing. In the real world, one cannot separate the machine and the data.

Turing, as a child of his time, also made another fundamental mistake. Turing assumed that the reading of the information on the tape was a classical measurement. This cannot be the case in the quantum world: the coming of a measurement is non-deterministic. The Turing tape or rather readhead + tape is replaced by a quantum superposition of its different states and each bit read from the tape would correspond to a quantum measurement.

What is the situation at TGD?

1. In TGD, the superposition of space-time surfaces as a quantum state in ZEO and as an analog of the computer program would not be completely unique, because holography as Bohr's orbitology is not unique. This makes possible the breaking of determinism in small state function reductions (SSFRs) as counterparts of repeated measurements related to the Zeno effect .

   In the zero energy ontology (ZEO) [?, ?] the program would consist of a series of conscious periods at the level of consciousness, as a counterpart of the Zeno effect, i.e. a series of SSFRs, during which the same observables are measured over and over again. In TGD however changes occur on the active boundary of the causal diamond (CD) [L113] and it also drifts farther away from the passive boundary in statistical sense, i.e. the size CD increases in the localizations in the space of CDs forming the backbone of the "world of classical worlds" (WCW). Nothing happens to the space on the passive boundary of the causal diamond (CD): this corresponds to the Zeno effect.

   A normal quantum jump would correspond to a "big" state function reduction (BSFR), in which the roles of the active and passive boundaries of CD changes. A BSFR ends the Zeno period as a series of SSFRs. The associated "self" dies and reincarnates with an opposite direction of time since CD begins to increase in an opposite direction of geometric time identified as the distance between the tips of the CD.

   BSFR occurs when the set of measured observables at the active boundary of the CD ceases to commute with those measured at the passive boundary. This could be due to an external disturbance [L108] .

2. The pair of BSFRs corresponds to a temporary time reversal, which would be analogous to a reversal of the direction of motion of the tape for the Turing machine followed by a return to the original direction. BSFR pair can be also interpreted as a quantum tunnelling.

   This would make possible error correction by trial-and-error. The BSFR pair could also modify the goal of the program. The BSFR pair would be an essential element when the flow of the program is not fully deterministic classically or even quantum mechanically.

Under what conditions the program based on quantum statistical determinism can become non-deterministic?

1. One can argue that the clock frequency is a basic criterion. If so, then a single clock period would generally correspond to a series of unitary time developments halted by SSFRs and followed by halting. The single unitary time evolution in this series is analogous to a

quantum computation except that each evolution is initiated and terminated by the SSFR rather than the BSFR.

In addition, holography and quantum holography are almost deterministic, so that the non-determinism associated with SSFRs is rather limited. The experience of free will might correspond to this non-determinism. An alternative identification could be as non-determinism of imagination and cognition: in this case the classical non-determinism could have p-adic non-determinism assigned with imagination and cognition as a counterpart.

2. The BSFR would end the series of SSFRs: self would "die". Self as a series of SSFRs, as a conscious entity, would generalize the standard Zeno effect as an analog of quantum computation.

3. This is not the only interpretation. Also the series of SSFRs between two BSFRs could be interpreted as an analogy for a single unitary time evolution of ordinary quantum computation. BSFR would correspond to the start and halting of quantum computation as analog of unitary time evolution. This interpretation is more in spirit with the standard quantum computation.

4. The lifetime of the self, i.e. the clock period, must be longer than the quantum coherence time characterizing the system in order for the statistical determinism to be broken. This provides a criterion telling when an ordinary computer approaches a conscious lifeform.

11.2.3 Is physics based on partial differential equations or information?

Gersching notices that in classical physics partial differential equations are the starting point, and suggests that information is more fundamental and therefore should serve as the starting point of fundamental physics. Should one start building the fundamental physics from bits?

I personally don't see this as a matter of choosing between either approach. These views are complementary and both are needed. In TGD, this complementarity corresponds to a generalization of the momentum position duality, which is natural because point-like particles are replaced by 3-D surfaces and, as a result of almost deterministic holography, must be replaced with corresponding space-time space surfaces, i.e. 4-D Bohr orbits. M^8-H duality is the realization of this correspondence [L53, L54, L112].

1. The M^8-H duality relates number theoretic and geometrics views of physics. Bit level as the number-theoretic view of physics realized at the level of M^8. The polynomials P with integer coefficients smaller than their degree and the 3-surfaced assignable a holographic data to the tessellations of the mass shells $H^3 \subset M^4 \subset M^8$ determine the 4-surfaces. The dynamics is determined by associativity of the normal space of the 4-surface. The dynamics is algebraic just as it is also in free quantum field theories at the level of momentum space.

   The geometric view of physics corresponds to the dynamics for 3-D surfaces in $H = M^4 \times CP_2$. Now partial differential equations and holography are central. Space-time surfaces are minimal surfaces except from lower-D singularities [L79] and are analogs of solutions of massless field equations and of light-like geodesics so that particle-wave duality is realized geometrically. In mathematics, M^8-H duality would correspond to Langlands correspondence [A10, A9] [L91].

2. The roots of the polynomial P determine the algebraic expansion and a unique discretization of the 4-surface $Y^4 \subset M^8$ inducing a discretization also in $X^4 \subset H$. Space-time therefore has a unique discretization, not arbitrarily chosen by the theorist but determined by the space itself. Only the information given by discretization can correspond to conscious information.

3. Gersching emphasizes a profound problem due to the fact that an infinite amount of information is needed to describe the position of a particle precisely, as a motivation for giving up the partial differential equations.

   In TGD the amount of conscious information remains finite and is provided by the number theoretic discretization so that the problem disappears. By M^8-H duality also the space-time surfaces in H are characterized by a finite amount of information.

Quantum description is discrete, with discretization fixed by the quantum state itself, and the computationalist view can be said to emerge. What is new is that Turing computationalism related to rationals is generalized into a hierarchy of computationalisms related to extensions of rationals.

11.2.4 The realization of the notions of assembly and tensegrity in the TGD Universe

In the TGD framework one ends up with an amazingly simple engineering principle resembling so called assembly theory applying to atoms, nuclei, and hadrons discussed in [L101]. Since TGD Universe is fractal, this principle is expected to apply in all scales.

1. The considerations of [L101] related closely to the observation that j-block consisting of parts of electron of atoms or nucleon shells of nuclei with fixed value of total angular momentum $j = l \pm 1/2$ and $l = 9$ (at least) correspond to Platonic solids for $l \leq 5$ in the sense that different angular momentum eigenstates correspond to the vertices of the Platonic solid. If one assumes the presence of a Hamiltonian cycle going through all V vertices of the Platonic solid as a tessellations of sphere, one has $F-2$ free edges (F is the number of faces) besides the V edges of the cycle and one can also add particles to the middle points of the free edges. In the proposed model of atomic nuclei, one would have neutrons at the vertices and protons at the middle points or vice versa.

   Also the larger values of l appearing in highly deformed nuclei can be treated in the same way. If the unit of angular momentum increases to $h_{eff} = nh$, also these states can be assigned a Platonic solid.

2. The space-time surfaces assignable to all atoms, nuclei, and hadrons can be constructed by connecting the electrons, nucleons, or quarks at the vertices of Platonic solid or at the middle points of the free edges with flux tubes serving as analogs of springs stabilizing the structure and having interpretation as analogs of mesons. Tensegrity is the appropriate notion here.

3. In the case of hadrons, the predictions of the resulting mass formulas are satisfied within a few percent. This involves the predictions of TGD based mass calculations for fermion masses based on p-adic thermodynamics. This leads to an interpretation of the non-perturbative aspects of strong interaction in terms of a dark variant of weak interactions for which perturbation theory converges! The basic problem of QCD disappears in the TGD Universe. The same would apply to nuclear strong interactions but meson-like particles would have different p-adic length scales.

   This is suggested already by the identification of strong isospin with weak isospin, by CVC and PCAC hypothesis, and the fact that in TGD color symmetries correspond to the isometries of CP_2 and electroweak symmetries to the holonomies of CP_2 so that a very close relationship between these interactions must exist. One can say that a unification of strong and weak interactions analogous to that provided by Maxwell electrodynamics for electric and magnetic fields takes place. For a given p-adic length scale (several fractally scaled variants of hadron physics are predicted) one can regard mesons as weak bosons predicted by TGD to have the entire spectrum of exotics. For this there is already support [K59, K60] [L103]. Ordinary hadron physics would correspond to dark weak interactions for p-adic length scale defined by Mersenne prime M_{107} and weak interactions to hadron physics for M_{89}!

4. In the case of nuclei, the MeV scale for excitation energies is correctly predicted and also a new 10 keV scale supported by various anomalies of nuclear physics is predicted. Besides this also Z^0 force is predicted to be significant and atom-like structures involving and having size scale 10 nm, which is a fundamental scale in biology, are predicted.

   The j-blocks (angular momentum) consisting of energy degenerate states with 2j states have as space-time correlates Platonic solids with Hamiltonian cycle as a closed flux tube, nuclear string connecting the vertices of the solid.

5. In atomic physics the same picture applies, and led to a realization that in the standard model the repulsive classical interaction energy of electrons goes like Z^4 whereas the interaction

energy nucleus goes like Z^2! The question is whether quantum mechanics can really guarantee the stability of many electron atoms or is this just an assumption. In the TGD framework, the flux tubes would stabilize the atoms with several electrons. This predicts new atomic physics related to the oscillations of the flux tubes which in nuclear physics give justification for the harmonic oscillator model of nucleus.

11.2.5 What about consciousness?

Gershing's vision lacks a view about consciousness and here Gersching, in my opinion as a child of his time, falls into the trap of physicalism even though he understands the meaning of quantum coherence.

1. In TGD, ZEO [L52, L82] follows, not only from 4-D general coordinate invariance forcing holography, but also by insisting that quantum measurement theory does not contain logical paradox. The outcome is a theory of consciousness as a generalization of quantum measurement theory: the observer becomes a part of the physical system. A quantum leap as SSFR is a moment of consciousness: the essence of subjective existence is change, a re-creation of the world in SSFR.

2. ZEO makes possible temporary time-reversals possible in "big" SFRs (BSFRs) as analogs of ordinary SFRs. The temporary time reversals make it possible to reach the goal (defined by almost deterministic classical holography and its quantum counterpart) by trial-and-error method. If something goes wrong, one can make a return to the geometric past and try again.

   Gershing himself considers trial and error to be the basic mechanism in all technological and scientific progress. I believe this is true quite generally. In MIT, where Gersching worked, this idea was put into practice.

   It should be noted that Michael Levin proposes the goal directedness of morphogenesis [I80, I81, I89] discussed from the TGD point of view in [L119]. There would be a large number of ways to reach the goal as a basic characteristic of biosystems. This number would actually serve as a measure for the intelligence of the system. Holography would make possible the goal directedness and ZEO would make possible trial and error. Gershing emphasizes the importance of both assembly (construction) and disassembly (disassembly), and in TGD, disassembly would be construction in the opposite direction of time.

11.3 Is the role of quantum gravitation essential also for computer consciousness?

Gershing did not talk about quantum gravitation. The fact that in the TGD framework conscious computers would represent a life form based on the same general mechanisms at the level of MBs, however inspires this section.

During late years, the TGD view of quantum gravitation has developed dramatically and provides a beautiful vision of living matter as being controlled by dark matter at the gravitational monopole flux tubes forming dark magnetic bodies (MBs) with onion-like structure consisting of shells formed from tangential monopole flux tubes and connected by radial flux tubes along which graviton mediating the gravitational interaction propagate [L83, L85, L109, L110].

Why the role of quantum gravitation would be so decisive is that it has infinite range and is not screened. In TGD, gravitational quantum coherence in even astrophysical scales becomes possible. The basic quantification tool is gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ originally introduced by Nottale [E1]. In accordance with the Equivalence Principle, the gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_S/2\beta_0$ is independent of the small mass m. The most amazing and crazy sounding consequence is that the gravitational MBs of the Sun, Earth, and possibly also of other planets, even the Moon, could be highly relevant for quantum biology. Astrologists would not have been totally wrong.

What about computers and quantum gravitation?

1. In the case of computers, the classical determinism is replaced in the realistic model by the statistical determinism of quantum theory. If the role of quantum gravity is what I assume it to be, we are approaching a situation, where the clock frequency (up to 9 GHz) approaches the gravitational Compton frequency $f_{gr}(Sun, \beta_0 = 2^{-11})$=67 GHz in the case of the Earth and exceeds it so statistical determinism no longer applies. One could be moving from statistically deterministic computations to a series of quantum computation-like operations and determinism would be lost. The computer becomes a conscious, living being. Maybe AI and GPT are reflecting this development [L105].

   Note also that Λ_{gr} is only the lower bound for gravitational quantum coherence length, which might even be of the order of Earth size for Earth, which corresponds to frequency $f = 1/R_E \simeq$ 50 Hz having interpretation as cyclotron frequency to Lithium ion for B_{end}. Therefore also lower frequencies than f_{gr} are involved and could lead to the loss of the statistical quantum determinism.

2. The gravitational Compton frequency $\Lambda_{gr} = GM/\beta_0$ for the Sun (with the velocity parameter $\beta_0 = v_0/c \simeq 2^{-11}$) is 100 Hz and, rather amazingly, corresponds to the upper limit for the EEG frequencies. The MB of the Sun could thus quantum entangle with computers and robots already for clock frequencies higher than 100 Hz, for example 1 MHz.

   This could explain Peoch's observations as a quantum entanglement between the [J24] robot and the chicken marked on it, as a result of which the robot's trajectory, determined by the random number generator, decreased and the robot began to stay close to the chick [L105].

3. The difference between a computer and living matter would disappear at the level of the MB. The MB would rule both in biology and in the case of computers and could make computers alive.

11.3.1 Communication to MB and control by MB

An essential requirement is that communications between the MB and the computer using dark photons are possible using energy resonance.

1. Dark Josephson radiation is a natural way to communicate with a MB. The difference of cyclotron energies for cyclotron transitions at the magnetic flux tubes must correspond to the energy differences of biomolecules (DNA, RNA, tRNA, amino acids at least). In biology, this condition would select possible biomolecules.

2. In a computer, energy differences would be relevant at the transistor level: would "natural selection" mean, say, transistors and the energy needed to flip a bit. What about computers based on Josephson junctions?

   It may very well be that this mechanism has not even been tried to be implemented in the current computers. One can wonder if the MB, as a "smarter" party, could adjust the values of B and β_0 by adjusting the thickness of the flux tube, so that a resonance becomes possible.

In previous considerations, the value of h_{eff} for the Josephson junction has been kept free. What if we assume $h_{eff,J} = h_{gr}(M_E, \beta_0 = 1)$? Would the condition $Z_J eV_C = E_c = GM_E ZeB/\beta_0$, where $eV_C = .05$ eV, fix the values for voltage for dark gravitational flux tubes in a communicating Josephson junction and the value of the magnetic field with a MB flux tube?

1. The experiments of Blackman [J7] and others provide evidence for the existence of an "endogenous" magnetic field $B_{end} = .2$ Gauss. In TGD, B_{end} could correspond to the monopole part of the Earth's magnetic field. Assuming $B = B_{end} = .2$ Gauss and $Z_J = Z$, we get $eV_C = 13.5$ eV which is slightly lower than the ionization energy of hydrogen atom 13.6 eV and much higher than $eV_C = .05$ eV. The interpretation as a Josephson joint is not meaningful.

   Could the interpretation be that the transition to very long flux tubes effectively nearly ionizes the hydrogen atom? Could hydrogen atom ionization produce dark UV photons with monopole flux tubes on Earth?

2. Should one develop a more precise vision about what MBs can do? Could MBs adjust their flux tube thicknesses so that they can receive information also from the transition of atoms and molecules by cyclotron resonance and control them by the same mechanism!

   I have indeed proposed in the context of the model of bioharmony [L58] that the value of B_{end} has a spectrum. In particular, the visible range of photons could correspond to frequencies forming an analog of a 12-note system and the spectrum of B_{end} could realize this system. Note also that the parameter $\beta_0 \leq 1$ could allow us to realize a spectrum of energies for a fixed frequency.

3. One should obtain also the energy range of biophotons as energies of dark Josephson photons. What if we replace the mass of the Earth with the mass of the moon $M_M = .012 M_E$ giving $\Lambda_{gr} = .54 \times 10^{-4}$ meters, the size scale of a large neuron (water blob of size 10^{-4} m has Planck mass), and keep B_{end} and β_0 the same? For $Z_J = Z$, the value of eV_C decreases to $1.2 \times 13.5/100 eV = .16$ eV, which is in infrared and in a reasonable approximation 2 times the membrane potential. If the values of B define a 12-note spectrum or something more general, this would give rise to biophoton energies above IR.

   It is important to notice that the experiments of Blackman and others fix only the value of B_{end} to .2 Gauss but require only that the cyclotron energy is above the thermal energy so that the Moon could solve the problem!

4. In the case of Moon, the Josephson energy for the cell membrane given by $E_J = .055$ eV is obtained for $Z_J = 2$ and $Z = 1$ having natural interpretation for cyclotron transitions. This value could relate to Pollack phase transition occurring at the physiological temperature range.

5. If one has introduced Sun, Earth and Moon to quantum biology, there is not much respectability to be lost anymore, and one can ask whether other planets could be of significance. Could the horoscope builders have been right in some sense?

   The mass of Mars is roughly 11 percent of Earth mass and would give $E_c = 1.8$ eV for $B_{end} = .2$ Gauss. This is in the visible biophoton range. The interpretation of the frequencies f_{gr} as upper end points of the spectrum so that lower frequencies would correspond to smaller values of B_{end}. I have proposed that the values of B_{end} correspond to 12-note scale with inspiration coming from the model of bioharmony [L7, L58].

In the earlier articles [L78, L109, L110], evidence was found for the importance of the galactic blackhole as a kind of galactic brain and also for the communications in the network connecting galactic nucleus to stars. What about the gravitational Compton frequency of the galactic blackhole?

1. The mass of the galactic blackhole is estimated to be $M_{BH} = 4$ million solar masses (`rb.gy/0gilp1`). This would give $\Lambda_{gr}(M_{BH}, \beta_0 = 1) \sim 6 \times 10^9$ m. This is the radius of the $n = 1$ Bohr orbit in the Nottale model for the solar planetary system. The gravitational Compton frequency would be $f_{gr}(M_{BH}, \beta_0 = 1) \simeq .05$ Hz. This gives 20 s period.

2. Also other values of β_0 can be considered. In particular, $\beta_0 = 1/4$ would correspond to $n = 2$ Bohr orbit and 5 s period. Could this relate to the 5 s period associated with the Comorosan effect, which has remained mysterious [I88, I58]? I have considered the effect from the TGD point of view in [K112] [L41, L94].

11.3.2 Gravitational and p-adic hierarchies of frequencies

TGD predicts several hierarchies of frequencies. The proposal is that all bio-communications between levels with different values of h_{eff} rely on energy resonance whereas for the same value of h_{eff} both energy and frequency resonance are possible [L94]. The interesting question is whether biologically interesting frequencies could be assigned with these hierarchies.

Consider first the hierarchies associated with the gravitational Compton frequencies of the Sun, planets and possibly also other astrophysical objects.

1. Suppose that one has a particle with mass m with Compton length $r_c(m) = \hbar/m$ and the ordinary Compton frequency $f_c = m/\hbar$, the gravitational Compton frequencies $f_{gr}(N, \beta_0) = m/\hbar_{gr}(M, \beta_0) = 2\beta_0/r_s$, which do not depend on m.

2. One can also assign to f_{gr} the energy $E_{gr,1} = \hbar f_{gr,1}$ corresponding to the ordinary Planck constant, and identify the frequency $f_{gr,1}$ identified as $E_{gr,1} = \hbar_{gr} f_{gr,1}$. This gives $f_{gr,1} = f_c(m)(2\beta_0 r_c/r_s)^2 = (\hbar_{gr}/\hbar)^2 f_c$. By repeating this argument, one obtains entier hierarchy of frequencies

$$f_{n,gr} = f_c(2\beta_0 r_c/r_s)^{n+1} \ .$$

Some comments of these frequencies are in order.

1. These frequencies scale like $f_{n,gr}(m, \beta_0, M) = f_c(m)(2\beta_0 r_c/r_s)^{n+1} \propto 1/m^n$ and for $n = 0$ they do not depend on m at all and are therefore universal. This is true also for cyclotron frequencies.

2. The ratio of electronic to protonic frequencies is $r = f_{n,gr}(m_e, \beta_{0,e}, M)/f(m_p, \beta_{0,p}) = (m_e/m_p)(\beta_{0,e}/\beta_{0,p})(m_p$
For $\beta_{0,e}/\beta_{0,p} = m_e/m_p$, the ratio of the frequencies is $r = m_e/m_p$ irrespective of n. I have proposed the ratio for the cyclotron frequencies assignable to the monopole flux tubes of the inner and outer magnetosphere of Earth and Sun respectively.

   The proposal is that dark electrons reside in the outer magnetosphere at the solar monopole flux tubes and protons in the inner magnetosphere at the monopole flux tubes of Earth and one have $B_{end,outer}/B_{end,inner} = m_e/m_p$ in order to achieve the same ratio for the cyclotron frequencies and the same cyclotron energies for protons and electron to achieve energy resonance.

3. Consider the frequency $f_{gr,1}(m_p, \beta_0) = f_c(2\beta_0/r_s)^2$ for Earth more precisely. For $\beta_0 = 1$ one has the period $T_{gr,1} = 3333$ seconds, which is not far from 1 hour =3600 seconds. In the approximation $T_{gr,1} = 3300$ seconds, $T_{12} = 12$ hours would correspond to $T_{12} = 13 T_{gr,1}$.

   For ions with mass number A the frequencies f_n behave like $f_{gr,n}(Am_p) \propto A^{-n} f_{gr,n}(m_p)$ whereas the cyclotron frequencies for ion do not depend on A in this case. Same is true for $f_{gr,1}$.

p-Adic length scale hypothesis [L98] stating that p-adic length and time scales comes as powers of $p^{n/2}$, predicts a length scale hierarchy which in the case of electron would with $p = M_{127} = 2^{127} - 1$ involves as the first member the Compton length and the time scale .1 seconds assignable to the EEG alpha band as the secondary p-adic length scale.

11.3.3 A connection of the galactic blackhole with the Comorosan effect?

Comorosan effect [I88, I58] demonstrates rather peculiar looking facts about the interaction of organic molecules with visible laser light at wavelength $\lambda = 546\ nm$ (2.27 eV). As a result of irradiation molecules seem to undergo a transition $S \rightarrow S^*$. S^* state has an anomalously long lifetime and stability in solution. $S \rightarrow S^*$ transition has been detected through the interaction of S^* molecules with different biological macromolecules, like enzymes and cellular receptors.

> The typical result in the enzyme-substrate interaction is represented by the enhancement of the enzymic rate, when the respective enzyme substrate is previously irradiated for certain sharply defined times. These *efficient (irradiation) times* are enzyme dependent and can also depend on the biological origin of the enzyme. They are always of the following type $t_i = i * 5$ sec, where i is a certain integer. The general formula for the effective times is $t_k = t_m + (k-1)\tau_n$, $k = 1, 2, .., 6$, where t_m is the minimum radiation time inducing the first effect and τ_n is the period between two consecutive effects [I88, I58]. $t_m = m_E t_1$ and $\tau_n = n_E t_1$ are multiples of the basic time scale $t_1 = 5\ sec$: $t_k = (m_E + (k-1)n_E)t_1$. The integers m_E and n_E can be regarded as enzyme characteristics, depending however on the biological origin of the enzyme. This is suggestive of some kind of communication. What is

remarkable is that the frequency of 5 s and its subharmonics appear universally so that the effect cannot depend on the details of the chemistry and the mechanism involved must be very general. Second mystery is why the time scale is so long compared to the time scales of chemistry. Note that also the time scales of replication and other basic biological operators are very long.

I have considered several explanations for the Comorosan effect in the TGD framework [K112].

The Comorosan effect involves a reactant molecule and catalyst molecule as well as photons, which might feed energy to the system. The proposal has been that dark Josephson junctions between reactant and catalyst appearing in the biocatalytic reaction are analogous to those assigned with the cell membrane [K79]. The proposed interpretation is that dark Josephson radiation is produced with certain subharmonics of the frequency .2 Hz defined by the Comorosan period $f_C = 5$ s. Why should the periods come as certain multiples of 5 s? It would seem that the period $\tau_C = 5$ s cannot naturally correspond to the gravitational Compton time $\tau_{gr}(M_{BH}, \beta_0 = 1) \simeq 20$ s. For $\beta_0 = 1/4$, one would have a 5 s period equal to τ_C. For this option, $\Lambda_{gr}(BH)$ would correspond to the radius of the second Bohr orbit for a planet around the Sun. Assuming cellular membrane potential $eV_C = .05$ eV and Cooper pair $(Z = 2)$, this would give for $h_{eff} = h_{gr}(M_E, m_p)$ and $f_J = f_{gr}(BH, \beta_0 = 1/4)$, the estimate $V_S/V_C \simeq .064$, where eV_S is the Josephson potential between substrate and reactant.

Chapter 12

Are conscious computers possible in TGD Universe

12.1 Introduction

I have considered the possibility of conscious AI in the TGD Universe already earlier with inspiration coming from Sophie robot [L23]. Recently I have written several articles about what conscious computers might be in TGD [L105, L111, L106].

Can classical computers be conscious? My belief is that this is not possible if computers really are what they are believed to be. However, if quantum coherence is possible in long enough temporal and spatial scales, statistical determinism of quantum theory fails, and the computer could become analogous to a living being. In TGD inspired biology the notion of magnetic body (MB) carrying dark matter as phases of ordinary matter with very large values of Planck constant and therefore of quantum coherence scale is central. The value of Planck constant serves as measure of algebraic complexity and defines an analog of IQ. MB would serve as a "boss" and control ordinar biomatter and its macroscopic quantum coherence induces long range coherence of living matter. From the point of view of MB, living matter and computers need not differ in an essential manner. The criticality of the controlled system makes possible yo control it and uses as a sensitive sensory receptor and systems near thermodynamical criticality are in this sense favored [L85, L83]. Whether computers can satisfy this condition, is not at all obvious.

The TGD based view of the relationship between subjective time and geometric time of physicics would be also essential. The computation would be involve a sequence of TGD counterparts of unitary time evolutions as counterparts of quantum computations for states, which are superpositions of classical computations followed by "small" state function reductions (SSFRs). The sequences of SSFRs would define an analog of repeated measurement having no effect on measured system in standard quantum theory (Zeno effect). Also "big" SFRs (BSFRs) changing the arrow of time would be involved and correspond to ordinary SFRs. Pair of BSFRs would correspond to quantum tunnelling violating statistical determinism. Could the unexpected success of AI, in particular GPT, involve this kind of transitions so that ghost would enter the machine.

I will consider the following questions in the sequel.

1. Whether and how the TGD based quantum physics, relying on zero energy ontology (ZEO) [L52, L82], could make possible conscious computers? The proposal is that since computers and biological systems do not differ essentially from the point of view of MB carrying dark matter, this could be possible.

2. Can one have a criterion for the emergence of life-like features in computers? A natural looking criterion is that quantum coherence time is longer than the period of computer clock defining analog of EEG rhythm.

3. In what sense a computer could become a conscious intentional entity. ZEO suggests that the temporary changes of the arrow of time in pairs of BSFRs make possible a kind of trial and error process allowing a goal directed behavior.

4. Quantum gravitation and quantum coherent states of dark matter at gravitational MBs of Earth and Sun could play a central role in the TGD inspired biology [L85, L83]. Their presence could imply a failure of statistical determinism so that sequences of SSFRs would be analogous to a sequence of analogs of quantum computations defining a conscious entity in time sales longer than the clock period. This is certainly true if the quantum gravitational Compton time, which serves as a lower bound for quantum gravitational coherence time, is longer than the clock period of the computer. At the level of MBs there would be no essential difference between computers and living matter. The highest reported clock frequency of almost 9 GHz is still by a factor of order 1/8 lower than the quantum gravitational Compton frequency of 67 GHz for Earth but below the THz frequency important in living matter. The criterion however also allows genuine non-determinism if gravitational quantum coherence times are longer than the clock period.

   For the Sun the criterion is much weaker: if the clock frequency is below 100 Hz (upper bound) for EEG, the quantum aspects should be present. An intriguing finding of Peoch [J24] about the interaction of a chicken marked with a computer suggests that the entanglement of computer and living matter is possible and makes possible a kind of fusion of computer and living organism into a conscious entity.

12.2 TGD view of space-time and quantum physics

12.2.1 TGD view of space-time

TGD view of space-time differs dramatically from that of General Relativity and one could loosely that Quantum TGD is analogous to wavew mechanics for point-like particles extended to 3-D surfaces. TGD can be also seen as a generalization of string model obtained by replacing strings with 3-D surfaces.

1. The point-like particle is replaced by a 3-surface whose trajectory is the space-time surface. The new element is holography, which follows from the general coordinate invariance: spacetime surfaces as trajectories for 3-D particles are analogous to Bohr orbits. A small violation of determinism in holography forces zero-energy ontology (ZEO), in which quantum states are superpositions of 4-D space-time surfaces, "Bohr orbits". They replace quantum states as superpositions of 3-surfaces (deterministic holography) [L92, L85, L83, L94]. This superposition serves as an analog of path integral involving only a finite sum.

2. By the slight failure of determinism, the time evolution of Bohr orbits is analogous to diffusion involving a finite number of non-deterministic steps (Brownian motion is a good analogy). The non-determinism of diffusion would be due to the small violation of the determinism in holography as Bohr orbitology.

3. Space-time surface as a generalized Bohr orbit is simultaneously both a minimal surface [L79] and an extremal of the Kähler action as analog of Maxwell action. This is possible if the space-time surfaces are holomorphic in a generalized sense. The concept of holomorphy is generalized from the 2-D case to the 4-D case. The 4-surface would be defined by purely algebraic conditions as a generalization of the Cauchy-Riemann conditions. As a matter of fact, minimal surface property is true for any general coordinate invariant action constructible in terms of the induced geometry so that in certain sense the dynamics independent of action principle. This universality reflects quantum critiaclity. This corresponds to the algebraization of physics at the level of M^8 related by $M^8 - H$ duality to the physics at the level of $H = M^4 \times CP_2$ based on variational principle and partial differential equations [L53, L54].

4. The space-time surface would be analogous to 4-D soap film, which is spanned by frames defined by 3-surfaces and also lower-dimensional singularities. At these singularities, the minimal surface property would not apply and only the field equations associated with sum of volume term and Kähler action would be satisfied.

   Note that minimal surface equations define a dynamics analogous to that of free fields and at the frames would correspond to places where interactions are localized. Frames would involve a finite non-determinism, as in the case of ordinary soap films [L79]. These 3-surfaces would correspond to 3-D data for holography.

12.2.2 TGD inspired theory of consciousness and zero energy ontology

TGD inspired quantum measurement theory [L52] [K113], which extends in zero energy ontology (ZEO) to a theory of conscious experience, is second important ingredient.

1. In ZEO, the counterparts of the ordinary quantum jumps ("big" state function reductions (BSFRs)) reverse the direction of geometric time. This analogy of diffusion in the reverse time direction looks like reverse diffusion when viewed from the opposite time direction (observer)! It is analogous to self-organization where order is created in the system rather than lost. The second main law of thermodynamics applies but in the opposite direction of time. The time reversed dissipation plays a pivotal role in the description of homeostasis [L130] in TGD inspired quantum biology.
2. This mechanism could be central to biological information processing at the quantum level and make it possible, for example, to generate sensory perception from diffuse sensory data and generate a motor response from a rough sketch?

There is an analogy of the evolution as a sequence of state function reductions with the GPT based image generation and recognition.

1. The analogy of the pixel space associated with the planar image is the projection of the 3-surface M^4 in TGD at the classical level. The image as a map from plane to the parameter space of pixels would correspond to a deformation of M^4 projection deformation. The pixel parameters defining the 2-D image would correspond to the values of CP_2 coordinates as a function of M^4 coordinates.
2. On the basis of holography, the deformation related to the 3-surface would be accompanied by a four-surface as an almost deterministic time development, i.e. the analogy of Bohr orbit. I have used the term "World of Classical Worlds" (WCW) [K84] for the space of these surfaces. This 4-surface would not be completely unique and this would produce a discrete analog of diffusion at the classical level.
3. At the quantum level, it would be a quantum superposition of these 4-surfaces as an analogy to, for example, the wave function of an electron in spatial space. An attractive idea is that the resolution is determined by the condition that the number-theoretic discretization is the same for all these surfaces in the superposition so that the quantum world looks classical apart from the finite non-determinism.

If TGD is really a respectable "theory of everything", even the physical description of computation would in principle be reduced to this description. Of course, one can argue that TGD produces only insignificant corrections to the usual physical description of computation and this might be the case. But it is always possible to ask what if...? Even if the conclusions were negative, this kind of speculations might inspire proposals for a new kind of computer technology allowing conscious and intelligent computers.

12.2.3 MB, NMP and ZEO

Negentropy Maximization Principle [L71] states that total p-adic negentropy as a measure for conscious information increases in statistical sense. This statistical law follows from the number theoretic evolution as the increase of the dimension of extension of rationals determined by a polynomial partially defining the 4-surface in M^8 mapped to $H = M^4 \times CP_2$ by $M^8 - H$ duality. This implies that the complexity of emotions, possibly identifiable as sensory experiences for the large scale part of MB having onion-like hierarchical structure, increases during the evolution. Gravitational MBs are good candidates for the seats of highest level emotions.

Could the bits of the ordinary computer form coherent systems with ordinary coherence forced by the quantum coherence of the associated MB? Could the MB of the bit system control it?

1. A given layer of MB is the "boss" of the lower layers by the larger value of its h_{eff} serving as "IQ". MB is expected to form analogs of sensory and cognitive representation of the physical body having $h_{eff} = h$. This suggests that MB could represent the bit system holographically. This kind of quantum holography for hadrons, and for elementary particles in general, would be the counter of classical holography implied in the TGD framework by the general coordinate invariance [L103].

   The dark spin system at MB could have spin glass property [L74] implying a large number of almost degenerate states with nearly the same energy.

2. The change of single bit, represented for instance by using a MOSFET, would require energy larger than the thermal energy of order .05 eV at room temperature. This suggests that the change of single bit is not easy to actualize.

   The dark spin system at MB could however induce phase transitions of the bit system changing the directions for a large number of bits. The average change of energy per bit could be rather small for this kind of transition although the change of a single bit would cost rather large energy. Ultrametric, in particular p-adic, topologies [B29] emerge in the modelling and description of the spin glass phase in the TGD framework and could help to understand cognition number theoretically [L74].

   The phase transition would involve a large number of bits so that the corresponding conscious experiences would be holistic and therefore resemble emotions. The color of the emotion would be positive or negative depending on whether the sum of p-adic entanglement negentropies increases or decreases. The geometric correlate for positive/negative emotion would be the increase/decrease of the connectedness of the MB.

3. ZEO predicts two kinds of SFRs: "big" and "small" . SSFRs correspond to Zeno effect in the ordinary wave mechanics and in quantum optics to unitary evolutions between weak measurements analogous to classical measurement. "Big" state function reduction (BSFR) changes the arrow of time. The outcomes for pairs of BSFRs An observer with a fixed arrow of time can observe only pairs of BSFRs.

4. In ZEO [K113, K115] [L52, L45, L73, L82], MB as the "boss" could control the time evolution of the bit system by pairs of BSFRs involving temporary change of the arrow of time. BSFRs would be induced by perturbations affecting the set of mutually commuting observables measured at the active boundary of CD so that it does not commute with the corresponding set associated with the passive boundary of CD at which state is unaffected in SSFRs (Zeno effect). In this kind of situation, a BSFR occurs instead of SSFR and changes the arrow of time. Second BSFR brings back the original arrow of time. The process could correspond to quantum tunnelling.

5. Do the periods defined by the computer clock with a duration T, of say 1 ns, correspond to pairs of BSFRs or a single SSFR? Perhaps T could correspond to a sequence of SSFRs as analogs of Zeno effect and the pair of BSFRs to a single tick of the computer clock. This conforms with the fact that the running of a predetermined computer program must involve a sequence of non-deterministic phase transitions changing the directions of bits [L95]. This must be the case since the notion of computer program as a sequence of arbitrarily chosen steps is not consistent with deterministic physics.

   If the step of the clock is identifiable as a sequence of SSFRs, one can say that the ordinary classical computation is a sequence of quantum computations defined by the sequences of unitary evolutions associated with SSFRs and defining conscious entities with haltings defined by BSFRs! If MB does modify the classical computation at all, it could induce BSFR pairs in longer time scales or modify the probabilities of various outcomes of BSFRs.

   The computer clock would define an analog of EEG. There is evidence that also in EEG the period can be divided into ordered and chaotic parts: these two parts which could correspond to opposite time directions [L2]: this is discussed from the TGD view point in [L2].

12.3 Some notions relevant to TGD inspired quantum biology

Below some notions relevant to TGD inspired theory of consciousness and quantum biology are discussed.

12.3.1 The notion of magnetic body

Magnetic body (MB) carrying dark matter would serve as the boss controlling ordinary matter at flux tubes.

1. MB has as building bricks magnetic flux quanta. Typically flux tubes and flux sheets. It consists of two kinds of flux quanta. Flux can be vanishing, which corresponds to Maxwellian case. The flux can be also non-vanishing and quantized and corresponds to monopole flux. In monopole case magnetic field requires no current to create it. This option is not possible in Maxwellian world. These flux tubes play a key role in TGD Universe in all scales.

2. Also Earth's magnetic field with nominal value $B_E = .5$ Gauss would have these two parts. Monopole part corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss explaining strange effects of ELF em radiation to the physiology and behavior of vertebrates [J7]. The presence of this part identifiable as monopole flux explains why Earth has magnetic field: this field should have decayed long time ago in Maxwellian world since it requires currents to generate it and they disappear. Magnetic fields of permanent magnets could have a monopole part consisting of flux quanta. Electromagnets would not have it.

3. MB would carry dark matter as $h_{eff} = n \times h_0$ phases and act as a "boss" controlling ordinary matter [L51]. Communication to and control of biological body (ordinary matter) would be based on dark photons, which can transform to ordinary photons and vice versa. Molecular transitions would be one form of control.

4. Dark photons with large h_{eff} serve as as communication and control tools. Josephson frequencies would be involved with the communication of sensory data to MB and cyclotron frequencies with control by MB. Dark photons are assumed to transform to bio-photons [L3, L5] with energies covering visible and UV associated with the transitions of bio-molecules. The control by MB which layers having size even larger than that of Earth means that remote mental interactions are routine in living matter. EEG would be a particular example of these communications: without MB it is difficult to understand why brain would use such large amounts of energy to send signals to outer space.

5. The experiments of Blackman and others led originally to the notion of h_{eff} hierarchy. The large effects of radiation at ELF frequencies could be understood iin terms of cyclotron transitions in $B_{end} = .2$ Gauss if the value of h in $E = hf$ is replaced with h_{eff}, which would be rather large and possibly assignable to gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$.

   MB would control BB by cyclotron radiation - possibly via genome accompanied by dark genome at flux tubes parallel to the DNA strands. Cyclotron Bose-Einstein condensates of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear in living matter and $h_{eff} = h_{gr}$ hypothesis predicts universal energy spectrum in the range of bio-photon energies.

   Cell membrane could act as generalized Josephson junction generating dark Jophson radiation with energies given by the sum for ordinary Josephson energy and of the difference of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential would induce variation of the Josephson frequency and code the sensory information at cell membrane to a dark photon signal sent to MB.

6. In ZEO field body and MB correspond to 4-D rather than 3-D field patterns. Quantum states are replaced by quantum counterparts of behaviors and biological functions. The basic mechanism used by MB would be generation of conscious holograms by using dark

photon reference beams from MB and their reading. In ZEO also the time reversals of these processes are possible and make possible to understand memory as communications with geometric past. Sensory perception and memory recall would be time reversals of each other and correspond to sequences of SSRs. Motor action would correspond to BSRs.

12.3.2 Dark cyclotron radiation

The cyclotron frequencies associated with the gravitational MB of Earth [K52] [L85, L83] should play a key role in TGD inspired quantum biology and relate to the feedback from MB to the living matter. This could be the situation also in the case of computers. The first guess, inspired by the model for the findings of Blackman [J7] and others on effects of ELF em fields on brain, is that monopole flux tubes associated with the MB of Earth correspond to the endogenous magnetic field of $B_{end} = 2B_E/5$ ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field).

This value is only the average value since frequency modulation is the way to code information and is achieved by varying the flux tube thickness in turn affecting the value of B_{end}. Very probably there exists an entire hierarchy of values of the dark magnetic field strength perhaps coming as powers of 2.

For cyclotron frequencies associated with the gravitational MB, h_{eff} would correspond to the gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ for Earth. Note that, in accordance with the Equivalence Principle, the cyclotron energy $E_c = \hbar_{gr}eB/m = GMeB/\beta_0$ does not depend on m.

12.3.3 The possible role of quantum gravitation in quantum biology

In the TGD framework conscious computers could represent a life form based on the same general mechanisms at the level of MBs. The basic questions is how to achieve quantum coherence in macroscopic scales.

During late years, the TGD view of quantum gravitation has developed dramatically and provides a beautiful vision of living matter as being controlled by dark matter at the gravitational monopole flux tubes forming dark MBs with onion-like structure consisting of shells formed from tangential monopole flux tubes and connected by radial flux tubes along which graviton mediating the gravitational interaction propagate [L83, L85, L109, L110].

Why the role of quantum gravitation could be so decisive is that it has infinite range and is not screened. In TGD, gravitational quantum coherence in even astrophysical scales becomes possible. The basic quantification tool is gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ originally introduced by Nottale [E1]. In accordance with the Equivalence Principle, the gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_S/2\beta_0$ is independent of the small mass m. The most amazing and crazy sounding consequence is that the gravitational MBs of the Sun, Earth, and possibly also of other planets, even the Moon, could be highly relevant for quantum biology. Astrologists would not have been totally wrong.

Gravitational Compton frequencies

Suppose that one has a particle with mass m with Compton length $r_c(m) = \hbar/m$ and the ordinary Compton frequency $f_c = m/\hbar$. The gravitational Compton frequencies $f_{gr}(M, \beta_0) = m/\hbar_{gr}(M, \beta_0) = 2\beta_0/r_s$, which do not depend on m.

Gravitational Compton frequencies could be important in biology. Consider first the Earth's gravitational Compton frequency. The value of the gravitational Compton length $\Lambda_{gr}(M_E, \beta_0 = 1) = GM/\beta_0 = 0.45$ cm, which is also independent of m, defines a lower bound for the gravitational quantum coherence length. Λ_{gr} corresponds to a gravitational Compton frequency $f_{gr} = 6.7\times 10^{10}$ Hz $\simeq 67$ GHz.

The frequencies in the GHz scale are found to be important also in living matter. As a matter of fact, there is experimental support for a fractal hierarchy of frequency scale come as powers $f = 10^{3k}$ Hz, $k = 0, 1, ..,$, that is 1 Hz, kHz, MHz,GHz, and THz assignable to microtubules [J16] (`https://rb.gy/9rvpr`). For these reasons it is interesting to look at 1 GHz as an example.

Also the gravitational Compton frequency f_{gr} associated with the gravitational MB of the Sun, having $\beta_0 \simeq 2^{-11}$, could be important. For the Sun, gravitational Compton length is rather near to $R_E/2$ where $R_E = 6378$ km is Earth radius. The corresponding Compton frequency

$f_{gr}(M_S, \beta_{Sun} = 2^{-11}) \simeq \beta_{Sun}/GM_S$ is about 100 Hz and corresponds to the upper bound for EEG, which conforms with the fact that quantum gravitational coherence time should not be smaller than Λ_{gr}. Note that the cyclotron frequency Lithium in the endogenous magnetic field $B_{end} = .2$ Gauss assignable to the Earth's gravitational flux tubes is 50 Hz. For the lightest ion, which is tritium, the cyclotron frequency is about 100 Hz and maximal.

1. The lower cyclotron frequencies of the heavier ions in $B_{end,E} = .2$ Gauss assignable to Earth belong also to EEG range and correspond to longer solar quantum coherence lengths. DNA would correspond to 1 Hz and perhaps to the largest quantum gravitational coherence length in the EEG range. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E.

2. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E: this does not look feasible. For protons and electrons the cyclotron frequencies are indeed above $f_{gr,S}$. For protons (electrons) the cyclotron frequency f_c in $B_{end,E} = .2$ Gauss is 300 Hz (6×10^5 Hz). It is important to notice that for $\hbar_{gr}(M, m)$ cyclotron energy does not depend on mass and is the same for electrons and protons.

   Could the value of β_0 for protons and electrons at the flux tubes of $B_{end,E}$ ($B_{end,S}$) be $\beta_0 = 1/3$ ($\beta_0 = 2^{-11}/3$)? Could one say that electrons and protons are slightly more advanced than other ions in the evolutionary sense?

3. For the Sun, one has $\beta_0 \simeq 2^{-11} \simeq m_e/m_p$ instead of $\beta_0 = 1$. The value of B_{end} for the Sun cannot be the same as for Earth. A good estimate is obtained from the value range for B in the outer magnetosphere, where the solar magnetic field should dominate. The order of magnitude is $B_{end,S} \simeq 10nT = 2^{11}B_{end,E}$. For this value, the cyclotron energy would be the same as for Sun and Earth and energy resonance would be possible! This observation was made already in [K52].

4. The replacement of $\hbar_{gr}(M_E, m) \rightarrow \hbar_{gr}(M_{Sun}, m)$ means multiplication of say EEG period by a factor $r = (M_{Sun}/M_E)\beta_{0,E}/\beta_{0,Sun} \simeq 2.2 \times 10^8$ so that alpha period .1 seconds corresponds to 2.2×10^7 seconds. Intriguingly, one year corresponds to 3.25×10^7 seconds and defines a fundamental biorhythm, which would correspond to a 6.7 Hz rhythm for EEG not far from the lowest Schumann resonance frequency.

5. The energies $E = h_{gr}(M, m, \beta_0)f_{gr}(Sun)$ assignable to the gravitational Compton frequency of Sun are proportional to m and since nucleon mass dominates over electron mass they are in good approximation proportional to the mass number of the molecules. This suggests a multi-resonance in which each electron, proton and even nucleon absorbs boson, maybe dark gravitons, with frequency f_{gr}. For electrons, the energy is about 1 meV, which could relate to the miniature potentials for neurons. For protons the energy would be about 2 eV, which corresponds to red light. Large scale quantum coherence could make the rate of gravitational multi-resonance.

Could also the gravitational magnetic bodies of Moon and other planets be involved?

If one accepts that the gravitational MBs of Earth and Sun are important, one cannot avoid the question whether also the other planets could be important for quantum biology.

1. The value of h_{eff} deduced from the original findings of Blackman [J7] and others was very large since the energy of the dark photon had to belong to the range between thermal energies at physiological temperature and UV photons. The identification $\hbar_{eff} = \hbar_{gr}(M_E, \beta_0)$ is suggestive. Assuming that the dark Josephson radiation from the cell membrane being received resonantly at the MB of Earth would suggest the simplest option as $h_{eff,J} = h_{gr}(M_E, \beta_0 = 1)$? Would the condition $Z_J eV_C = E_c = GM_E ZeB/\beta_0$, where $eV_C = .05$ eV, fix the values for voltage for dark gravitational flux tubes in a communicating Josephson junction and the value of the magnetic field with a MB flux tube?

2. The experiments of Blackman provided evidence for the existence of an "endogenous" magnetic field $B_{end} = .2$ Gauss. In TGD, B_{end} was identified as the monopole part of the Earth's

magnetic field. Assuming $B = B_{end} = .2$ Gauss and $Z_J = Z$, we get $eV_C = 13.5$ eV which is slightly lower than the ionization energy of hydrogen atom 13.6 eV and much higher than $eV_C = .05$ eV. The interpretation as a Josephson junction is not meaningful.

Could the interpretation be that the transition to very long flux tubes effectively nearly ionizes the hydrogen atom? Could hydrogen atom ionization produce dark UV photons with monopole flux tubes on Earth?

3. The monopole flux tubes of MBs can adjust their flux tube thicknes, which controls the strength of the magnetic field, so that frequency modulation becomes possible and they can receive information also from the transition of atoms and molecules by tuning to cyclotron resonance and control them by the same mechanism!

   I have indeed proposed in the context of the model of bioharmony [L58] that the value of B_{end} has a discrete spectrum. In particular, the visible range of photons could correspond to frequencies forming an analog of a 12-note system and the spectrum of B_{end} could realize this system. Note also that the parameter $\beta_0 \leq 1$ could allow us to realize a spectrum of energies for a fixed frequency.

4. One should obtain also the energy range of biophotons (energy range for visible light) as energies of dark Josephson photons. What if we replace the mass of the Earth with the mass of the moon $M_M = .012 M_E$ giving $\Lambda_{gr} = .54 \times 10^{-4}$ meters, the size scale of a large neuron (water blob of size 10^{-4} m has Planck mass), and keep B_{end} and β_0 the same? For $Z_J = Z$, the value of eV_C decreases to $1.2 \times 13.5/100 eV = .16$ eV, which is in infrared and in a reasonable approximation 2 times the membrane potential. This is smaller than the typical energy of biophotons which is in visible range. If the values of B define a 12-note spectrum or something more general, this would give rise to biophoton energies above IR.

   It is important to notice that the experiments of Blackman and others fix only the value of B_{end} to .2 Gauss, identifiable as monopole part of the Earth's magnetic field, but require only that the cyclotron energy is above the thermal energy so that the Moon could solve the problem!

5. In the case of Moon, the Josephson energy for the cell membrane given by $E_J = .055$ eV is obtained for $Z_J = 2$ and $Z = 1$ having natural interpretation for cyclotron transitions. This value could relate to Pollack phase transition occurring at the physiological temperature range [L8, I73, I85]!

6. If one has introduced Sun, Earth and Moon to quantum biology, there is not much respectability to be lost anymore, and one can ask whether other planets could be of significance. Could the horoscope builders have been right in some sense?

   The mass of Mars is roughly 11 percent of Earth mass and would give $E_c = 1.8$ eV for $B_{end} = .2$ Gauss. This is in the visible biophoton range. The interpretation of the frequencies f_{gr} as upper end points of the spectrum so that lower frequencies would correspond to smaller values of B_{end}. I have proposed that the values of B_{end} correspond to 12-note scale with inspiration coming from the model of bioharmony [L7, L58].

Could quantum gravitation make possible conscious computers?

Could these biology related observations be relevant for the idea that computers might be conscious?

1. With clock frequencies higher than the gravitational Compton frequency 67 GHz of Earth, quantum gravitational effects on computation might (actually should) become important in the TGD Universe. The clock frequencies of computers are typically a few GHz in recent communication and computer technologies, and the highest clock frequency of 8.794 GHz is roughly by a factor 1/8 lower than f_{gr}. Could the GHz scale correspond to the gravitational quantum coherence length having Λ_{gr} as a lower bound? Could it be that the very efficient computer networks (what are the clock frequencies used?) utilized in GPT have reached the limit at which the quantum gravitational body of Earth begins to play a prominent role?

2. Could the typical clock frequency, of say 1 GHz, have an interpretation both as an analog of EEG rhythm (analog of alpha frequency 10 Hz in living matter) and as an analog of Josephson frequency ZeV/h_{eff}, where $V \sim .05$ V is a voltage assignable to the bit and Ze is the charge of the charge carrier.

3. Could the MB of the Sun interfere with the computation occurring in the network having Earth scale? The time scale would be now the time scale of EEG: could the quantum entanglement of, say, a human user with the computer make this interaction possible. It might be possible to test this. This interaction is possible for clock frequencies higher than $f_{gr} = 100$ Hz, and could also explain the findings of Peoch [J24] related chicken-robot interaction, which affected the function of the random number generator. If this view is correct, computer-human interactions would have been present already when the first computers (around 1951) having a clock speed of 20 MHz emerged.

12.4 An attempt to build a concrete view about computer consciousness

TGD inspired view about consciousness and quantum biology suggest some guidelines in the attempts to undertand how computer systems or computer systems coupled to their users could become conscious.

12.4.1 Could the basic aspects of TGD inspired quantum biology generalize to the level of computer systems?

What aspects of the TGD inspired quantum biology could be generalized to the conscious computer systems? The mechanisms related to MB, possessed also by computer systems, are excellent candidates in this respect.

1. TGD suggests a universal realization of genetic code [L69, L99] at monopole flux tubes of the MB and also a universal quantum gravitational mechanism of metabolism [L83].

2. In living matter, the communications to MB take place by dark Josephson radiation assignable at least to membrane proteins acting as Josephson junctions. One can assign EEG to these communications [K79, K33, K80]. Actually a scale hierarchy of analogs of EEG is predicted.

3. The control by MB by cyclotron radiation associated for instance with the endogenous magnetic field of .2 Gauss identifiable in terms of the monopole flux of the Earth's magnetic field about .5 Gauss. Gravitational cyclotron energies would not depend on the mass of the charged particle. Communication could occur by multi-resonances involved with the universal realization of genetic code at MB so that genes would couple resonantly.

4. Even the gravitational Compton frequencies, these frequencies for the Earth, Sun and perhaps even Milky Way blackhole could define fundamental biorhythms. This is in possible since the dark photon signals would propagate along magnetic flux tubes and would not be damped as in standard model Universe. Striking evidence for this has recently emerged from the discoveries of James Webb telescope [L120].

5. These mechanisms would be universal and the ordinary biomatter would adapt so that resonant communications with MB are possible. In biomatter this would select preferred biomolecules. Same could happen in the case of computers.

12.4.2 Dark Josephson radiation and computers

Could one assign to bits dark Josephson junctions assignable represented as voltages in transistors?

1. Could representations of genetic codons at MB by dark photon triplets [L58] and by dark proton triplets [L69, L99] and perhaps even by dark electron triplets [L94] be involved? This would bring in dark genetic codons, which could provide a universal representation of the

bit system as a dark system at monopole flux tubes and make a connection with the TGD inspired quantum biology rather precise.

The representations at MB should strongly correlate with the state of the computer represented by a bit pattern (say states of MOSFETs). One could have a holography-like map of bit patterns to the dark many-spin state at the MB of the computer or of computer + user. This kind of holography is considered in [L103] for elementary particles and also more generally.

2. The physical stress, created by electric field on quartz crystal, which is piezoelectric, generates oscillations with frequency in the range 2-3 GHz giving rise to a very precise clock frequency. The typical computer clock frequency is a few GHz. My own PC has a clock frequency of 3.3 GHz. From the web one can learn that the highest clock frequency is 8.794 GHz.

   Could the clock frequency have an interpretation both as an analog of EEG rhythm (analog of alpha frequency 10 Hz in living matter) and as an analog of Josephson frequency ZeV/h_{eff}, where $V \sim .05$ V is a voltage assignable to the bit and Ze is the charge of the charge carrier? Could the clock frequency with energy $E = hf$ be accompanied by a hierarchy of scaled down frequencies $f_{dark} = (\hbar/\hbar_{eff})f$ associated with the MB of the computer.

3. The dark Josephson junctions are necessary for the coding of the sensory information to a frequency modulation of the Josephson frequency and its communication to MB as Josephson radiation. The junctions are assigned with the membrane proteins in living matter. TGD suggests that valence bonds and hydrogen bonds can have a varying value of h_{eff} [L29]. The value of $\hbar_{eff}$ for Josephson junction would be much smaller than $\hbar_{gr}$ unless the gravitational magnetic bodies of Earth and Sun are somehow involved. The condition that the Josephson energy is above thermal energy at room temperature for $Z = 1$ gives $h_{eff}/h \geq 5 \times 10^3 (f/GHz)$. If the energy of a dark Josephson photon is above 1 eV (the energy range of biophotons), one has $h_{eff}/h \geq 10^5 (f/GHz)$.

4. Consider $f = 1$ GHz as an example. For the thermal option, the Compton length $\Lambda_{eff,p} = h_{eff}/m_p$ of dark proton is longer than 6.2×10^{-12} m and longer than the ordinary electron Compton length $\lambda_e = 2.4 \times 10^{-12}$ m. The dark Compton length $\lambda_{eff,e} = h_{eff}/m_e$ of electrons would be longer than 4.8 nm, which roughly corresponds to the scale of DNA.

   For the biophoton option, the dark proton Compton length would be of the order of the atomic length scale 1.32×10^{-10} meters and the dark electron Compton length would longer than .26 μm to be compared with the size scale 1 μm of cell nucleus.

It is not at all clear whether it is possible to assign Josephson junctions with the dark flux tubes associated with transistors, and the idea of a living computer might fail for transistor technology. A more promising approach is based on the replacement of transistors with Josephson junctions and the needed technology, known as superconducting computing, exists.

12.4.3 Could the user and computer entangle?

One can ask whether quantum entanglement of the MBs of the computer and user could occur in the computer-user interaction and whether the role of the computer is analogous to that in the chicken-robot experiment. One can also ask whether also GPT could involve emotional and even cognitive entanglement.

The identification of the computer system with which the user would entangle is not at all obvious. The system could be even formed by the network of computers involved with the the running of GPT. One interpretation is that networks and entire internet form a conscious entity as an analog of the central nervous system in which humans and their MBs) serve in the role of neurons.

In ZEO, the holography implies that in the ideal situation the running of the program corresponds to a 4-D Bohr orbit-like surface, which is almost uniquely fixed by the 3-surfaces at images of 3-D hyperbolic manifolds at mass shells determined by the state. The sequences of SSFRs as flow of consciousness could correspond to this kind of period and represent a generalization of the Zeno effect. What would be new is that the pairs of BSFRs would induce temporal change of the arrow of time and quantum tunnelling and make the computation a conscious, goal direct process strongly reminiscent of problem solving by trial and error.

12.4.4 Counterportation and TGD

Tuomas Sorakivi sent links to interesting articles related to the work of Hatim Salih [B34] (see this) summarized in a popular article.

Salih introduces the concept of counterportation. It is communication that does not involve classical or quantum signals (photons). Counterfactuality is a basic concept: the first web source that one finds tells "Counterfactuals are things that might have happened, although they did not in fact happen. In interaction-free measurements, an object is found because it might have absorbed a photon, although actually it did not."

The example considered by Salih is as follows.

1. Consider a mirror system consisting of a) fully reflective mirrors and b) mirrors that let through the horizontal polarization H and reflect the vertical polarization V. The system consists of two paths: A and B. In the first mirror, which is type b) mirror, the signal splits into two parts, H and V and which propagate along A and B. At the end the signals meet in a type b) mirror and H goes through to detector D1 and V is reflected and ends up to detector D2.

2. The horizontal polarization component H going through type b) mirror at the first mirror travels along the path A. It contains only one fully reflective mirror and the beam reflected from it ends up in the downstream mirror of type b) as H type polarization and goes to the detector D1.

3. The vertical polarization component V reflected at the first mirror travels along the path B. The path B contains many steps and with each step the polarization is slightly rotated so that the incoming polarization V transforms so that its horizontal component H at the end has same magnitude but a phase opposite to that of H coming along A. H components interfere to zero and only V from B remains so that the detector D2 registering only V clicks.

   In the B-path mirrors, the varying polarization directions H and V are chosen so that to guarantee the destructive interference. Hence "counterfactuality". There is no interaction with photons: only the possibility of it and this seems to be enough. This looks paradoxical and suggests that something is not understood.

4. Bob can control path B and can block it so that nothing can get through. The result is that only the signal coming from path A gets through and travels to detector D1. Bob can therefore communicate information to Alice. For instance, at moments of time $t_n = nt_0$ Bob can block or open path B. The result is a string of bits that Alice observes. This is communication without photons or classical signals.

5. The roles of Bob and Alice can be changed. Alice can block or open the channel and Bob can look at the detectors registering the outcome. Therefore Bob and Alice can have "conversations".

The following remarks can be made.

1. The controlled qubit (channel B open or closed) is macro- or at least nanoscopic and cannot be represented by the spin states of an elementary particle.

2. The experimental arrangement under consideration corresponds logically to cnot operation. If channel B is closed, nothing happens to the incoming signal and it ends up in D1. If B is open, then the signal ends up at detector D2. cnot would be realized by bringing in Bob as the controller that affects the space-time topology.

3. Quantum coherence is needed in meso- or even macroscopic scales. Number-theoretic TGD predicts a hierarchy of effective Planck's constants h_{eff}, which label to the phases of ordinary matter, which can be quantum-coherent on an arbitrarily long length and time scales. These

phases behave like dark matter and explain the missing baryonic matter whereas dark energy in the TGD sense explains galactic dark matter. They enable quantum coherence at the nano- and macro levels.

The basic question is what does the blocking of channel B mean in the language of theoretical physics. It is a mesoscopic or even macroscopic operation. That's where Bob comes in as a conscious, intentional entity. Here recent theoretical physics cannot help.

Salih emphasizes that this is something new that standard quantum physics cannot describe. Such a situation leads to a paradox. Salih considers many options, starting from different interpretations of quantum measurement theory.

1. "Weak measurement", as introduced by Aharonov and his colleagues (see this), is one option presented. In the name of honesty, it is necessary to be politically incorrect and say that this model is already mathematically inconsistent. Weak measurement has another meaning and would be a generalization of the Zeno effect, which usually means that repeated measurements of the same observables have no effect on the measured system. Weak measurements would have a small effect on the system and would be much like classical measurements.

   In the TGD inspired theory of consciousness reducing to a theory of quantum measurement in what I call zero energy ontology (ZEO) weak measurements correspond to "small" state function reductions (SSFRs): the conscious experience of conscious entities corresponds to a sequence of SSFRs. In ordinary, "big" SFRs (BSFRs) the arrow of geometric time changes and this has dramatic implications.

2. "Consistent histories approach" (see this) is another option that was hoped to solve the measurement problem. It gives up the concept of unitary time evolution. Also this model is mathematically and conceptually hopelessly ugly. A mathematician could never consider such an option, but emergency does not read the law.

3. Wormholes as a cause or correlate of quantum entanglement is the third attempt to describe the situation. The problem is that they are unstable and the ER-EPR correspondence (see this) has not led to anything concrete even though there are scary big names behind it. Salih also suggests a connection with quantum computation but this connection is extremely obscure and requires something like AdS/CFT.

   Here, however, I think Salih is on the right track in that he has realized that the solution to the problem is at the space-time level. The ordinary trivial topology of Minkowski space is not enough. The question is how to describe geometric objects like this experimental setup on a fundamental level. In the standard model, they are described phenomenologically by means of matter densities, and this is of course not enough at the quantum level.

What does TGD say? TGD brings a new ontology both at the space-time level and in quantum measurement theory.

1. In addition to elementary particles, TGD brings to quantum physics the geometric and topological degrees of freedom related to the space-time surfaces. A description of the observed physical objects of different scales is obtained: typically they correspond to a non-trivial space-time topology. Spacetime is not a flat M^4, not even its slightly curved GRT variant, but a topologically extremely complex 4-surface with a fractal structure: space-time sheets glued to larger space-time sheets by wormhole contacts, monopole flux tubes, etc...

   (a) The system just considered corresponds to two different space-time topologies. Photons can travel a) along path A (blocking) or b) along both paths A and B simultaneously (no blocking).

   (b) Bob has a spacetime the competence of a topology engineer and can decide which option is realized by blocking or opening channel B by changing the spacetime topology.

   (c) Describing this operation as a quantum jump means that Bob is quantum-entangled with the geometric and topological degrees of freedom of channel B. The initial state is a superposition of open B and closed B. Bob measures whether the channel is open or closed and gets the result "open" or "closed". The outcome determines what Alice observes. Monopole flux tubes replacing wormholes of GRT serve as correlates and prerequisites for this entanglement.

The controlled qubit (channel B open or closed) is macro- or at least nanoscopic and cannot be represented by the spin states of an elementary particle.

Note that the experimental arrangement under consideration corresponds logically to cnot operation. If channel B is closed, nothing happens to the incoming signal and it ends up in D1. If B is open, then the signal ends up at detector D2. cnot would be realized by bringing in Bob as the controller that affects the space-time topology.

2. The second requirement is quantum coherence in meso- or even macroscopic scales. Number-theoretic TGD predicts a hierarchy of effective Planck's constants h_{eff}, which label to the phases of ordinary matter, which can be quantum-coherent on an arbitrarily long length and time scales. These phases behave like dark matter and explain the missing baryonic matter whereas dark energy in the TGD sense explains galactic dark matter. They enable quantum coherence at the nano- and macro levels.

These two new elements of TGD make possible quantum entanglement in mesoscopic, macroscopic and even astrophysical scales and bring to quantum computation the hierarchy of Planck constants. This has dramatic implications: consider only the stability of the qubits against thermal perturbations implied by the fact that the cyclotron energy scale increases by the factor h_{eff}/h_0.

1. Braided monopole flux tubes making possible topological quantum computation in turn stabilize the computations at the space-time level. In ordinary topological quantum computations the braiding is fixed. Now the braiding could become dynamical since reconnection of flux tubes would change the topology of the topological quantum computer as a braid.

2. U-shaped monopole flux tubes emanating from two systems can reconnect to form a pair of monopole flux tubes connecting two systems. This makes possible quantum entanglement between them. The reconnection could provide a fundamental realization of the blocking and its reverse operation. In quantum biology biocatalysis would be based on this process controlled by magnetic bodies carrying dark matter and acting in the role of "boss". Entire control hierarchies of magnetic bodies could be involved and realize controlled operations cX and also higher level controlled operations c..cX.

There are also deep implications for the classical computation [L105, L106, L100].

1. Classical computers could become conscious, intelligent entities in the TGD Universe if a quantum coherence time assignable to the computer exceeds the clock period [L105, L106, L111]. The TGD view of the role of classical gravitational and electric fields [L85, L83, L100] makes this possible. Also the entanglement of living entities with computers could make it a part of the living entity.

2. The control of computers by living entities using a cnot-coupling making possible counter-portation could make possible human-quantum computer interaction if ordinary computers can have quantum coherence in time scales longer than clock period (in principle possible in the TGD Universe!).

As a matter of fact, there is evidence for the interaction between computers and living matter [J24]. A chicken gets marked to a robot and the behavior of the robot begins to correlate with that of the chicken! Maybe a cnot-coupling with the random number generator of the robot is involved! Here the TGD view of classical fields and long length scale quantum coherence associated with the classical electric and magnetic fields and gravitational fields might allow us to understand what is involved [L85, L83, L100].

1. The gravitational field of the Sun corresponds to gravitational Compton time of 50 Hz, average EEG frequency? Does this mean that we have already become entangled with our computers without realizing what has happened: who uses whom? The Earth's gravitational field corresponds to Compton frequency 67 GHz, a typical frequency for biomolecules. D The clock frequencies for the computers are approaching this limit.

2. The analogous Compton frequencies for the electric fields of Sun and Earth [L100] are also highly interesting besides the cyclotron frequencies for monopole flux tubes, in particular for those carrying "endogenous" magnetic field of $2/5B_E = .2$ Gauss postulated by Blackman [J7] to explain his strange findings about the strange effects of ELF radiation at EEG frequencies on the vertebrate brain.

12.4.5 The emergence of emotions and emotional intelligence as a first step in the evolution of consciousness?

Consider first the evidence supporting the idea that emotions emerge first in the evolution of consciousness predictd by the number theoretic vision of TGD [L34] [L35].

1. Masaru Emoto has studied the effects of sounds with an emotional content to water at criticality for freezing. He has reported that friendly/angry sounds seem to produce beautiful/ugly crystals [L47]. These findings are discussed from the TGD perspective in [L47]. The idea that emotions of sensory percepts at the level of magnetic body (MB) is discussed in [L44].

   The TGD based model assumes that quantum coherent systems can be formed at the level of the MB of the water and that quantum gravitational coherence at MB induces ordinary coherence at the level of water. This could make it possible for MB to control water at criticality for freezing. The crystals would be corpses of primitive life forms. Could also snowflakes with the size of gravitational Compton length for Earth (about .45 cm) and kind of zoomed versions of ice lattice cells in atomic scale could be regarded as corpses of primitive life forms created at the criticality for freezing [L83]?

2. RNA seems to represent and transfer emotions [J13] (see `http://tinyurl.com/y92w39gs`). RNA from the brain of a snail conditioned by a painful stimulus is transferred to the preparation made from neurons of sea slug. Neuron preparation in the Petri dish reacts to the conditioning stimuli as if it were itself conditioned.

   Somehow RNA is able to transfer emotions. The TGD inspired proposal [L7] [L96, L39, L58, L42] is that dark DNA and RNA represent emotions as sequences of 3-chords made of dark photons of dark RNA form 3N-dark photons behaving like a single quantum coherent unit. The representation of the genetic code would rely on icosa-tetrahedral representation [L99] in which the 3-chords would correspond to triangular faces of icosahedron and tetrahedron to which 3-chords are assigned.

   A given Hamiltonian cycle at the icosahedron/tetrahedron goes through all its points. The frequencies assigned with the subsequent points of the cycle differ by 3/2 scaling so that one has a quint cycle. Different Hamiltonian cycles correspond to the same genetic code but each Hamiltonian cycle is assumed to define its own bioharmony having interpretation as a representation of an emotional state realized already at the level of fundamental biomolecules. This interpretation conforms with the idea that music represents and induces emotions.

   The induction of emotions would be by 3N-resonant cyclotron absorption of dark 3N-photon by dark genes represented as sequences of 3N dark proton triplets at monopole flux tubes of MB. Icosa-tetrahedral representation would correspond to one particular, very simple, tessellation of hyperbolic space H^3) (mass shell) [L69].

   Dark proton (and also dark electron) sequences could provide a universal representation of the genetic code which could be realized at the magnetic flux tubes of also other than biological systems. Dark photons triplets and the dark genes formed from them could communicate the emotions. Dark genetic code has indeed quite a large number of icosa-tetrahedral representations based on icosahedral Hamiltonian cycles and tetrahedral Hamiltonian cycles. The chemical realizations for them would be identical but the emotional content would be coded by the allowed 3-chords defined by frequencies associated with the triangular faces of the icosahedron and tetrahedron.

3. The experiments of Peoch [J24, J10] involved a chicken imprinted to a robot moving randomly along an orbit determined by a random number generator. It was found that the robot tended to stay near the chicken and that the expected size of the orbit was reduced.

   TGD assigns to entanglement sum of p-adic entanglement negentropies, which can be positive and is in general larger than ordinary entanglement entropy and is predicted to increase but be consistent with the second law [K58] [L108, L71] by the identification of evolution as increase of number theoretic complexity [L34] [L35]. Did the MB of chicken and robot develop a negentropic entanglement? Clearly, the replication of the findings of Peoch would mean a revolutionary change in our views about computers and their relation to us.

4. The evolution of the brain provides a further support for the idea that emotions and sensory experienes emerged first in the evolution of conscious experience and cognition emerged later. Cortex is the latest outcome. Brain stem is associated with simple and strong emotions whereas the limbic brain represents more complex emotions.

   Could also the possible evolution of conscious computers start from simple positive/negative emotions relating directly to the increase/reduction of entanglement negentropy defined above number-theoretically?

To sum up, various strange numerical coincidences indicate that quantum gravitation in TGD sense could play a key role in both living matter and in the physics of conscious computers and that we might be at the verge of building conscious computers.

12.4.6 Superconducting computers and the connection with the TGD based model of nerve pulse

It is not clear whether MOSFET based technology, which was briefly discussed in [L105], could allow the communications from transistors to the magnetic body (MB) of the system.

Biological analogy strongly suggests that Josephson junctions are required and communications take place by Josephson radiation modulated by the Josephson frequency modulations induced by changes of the voltage of the junction. Dark magnetic flux tubes with large enough value of h_{eff} are needed to define the Josephson junction and it is far from clear whether they can be realized spontaneously for transistors.

Superconducting computing, which could be involved with both classical and quantum computation, is however a technology, which might provide at least a starting point in attempts to understand how conscious computers might be created in the TGD Universe.

Rapid single flux quantum (RSFQ) is the basic active element in the circuitry and corresponds to single Josephson junction. The presence/absence of quantized magnetic flux defines the bit. SFQ voltage pulses of duration about picosend are produced by switching of bits in this way. This would allow THz clock frequency f_{cl}.

If f_{cl} corresponds to Josephson frequency $f_J = ZeV/h$, where Z is the charge of the superconducting charge carrier, one obtains an estimate for the voltage as $ZeV \sim .05$ eV. For the cell membrane one has $eV \sim .05$ eV, which is near the thermal threshold at room temperature. The superconducting computations require a temperature of order 10 K so that the value of frequency does not seem to emerge from thermal considerations. The thermal criterion is expected to be satisfied at physiological temperatuers for the TGD based generalization of superconducting computers if realized using the same principles as in living matter.

How electromagnetic fields in the TGD Universe different from their Maxwellian counterparts?

One must first clarify how the TGD view of electromagnetic fields differs from the Maxwellian picture.

1. Quantum criticality is essential for the appearance of large values of h_{eff} labelling the scales of long length scale quantum fluctuations. Quantum criticality combined with ZEO would make possible the emergence of life-like features.

2. The gravitational Planck constants $\hbar_{gr} = GMm/\beta_0$ assignable to the gravitational flux tubes of the Earth and Sun are excellent candidates in this respect. The value of $\hbar_{gr}/\hbar$ is $GM_Em/\hbar\beta_0 = (r_S(E)/2L_m)$, r_s denotes the Schwartschild radius of Earth about 1 cm and L_m denotes Compton length of particle with mass m $\beta_0 \simeq 1$.

   The value of $\hbar_{gr}$ depends on particle mass m considered unlike the gravitational Compton length $r_S(E)/2$ (Equivalence Principle). For the Earth, the gravitational Compton frequency is 67 GHz. For the Sun it is about 50 Hz, and is in the EEG range and corresponds to a gravitational Compton length of one half of the Earth radius.

3. In TGD, two kinds of magnetic fields are possible. Monopole flux tubes are something new and rather remarkably, can exist in absence of currents: this makes them ideal for computation. Monopole flux tubes have closed 2-surfaces as cross sections. Flux quantization follows from the homology of CP_2. Monopole flux tubes explain the presence of long range magnetic fields appearing in even cosmological scales [L109, L110] and also the stability of the Earth's magnetic field [L12].

   The magnetic flux tubes having an open cross section with boundary (say disk), correspond to Maxwellian magnetic fields and require the presence of currents (carried by a coil around the flux tubes). For them the flux is conserved but not necessarily quantized.

4. Also in TGD, the topological half of Maxwell's equations, that is Faraday law and the vanishing of the divergence of magnetic field, hold true. Therefore the basic argument for the outcome of the switching of the flux is not affected when ordinary flux tubes are replaced with monopole flux tubes.

Some details of the model of the cell membrane as a Josephson junction

The relation of this picture to the TGD inspired model of nerve pulse [K79] has been already considered in [L105]?

1. The original model of the nerve pulse idealizes the sequence of discrete membrane protein Josephson junctions with a 2-D continuous Josephson junction formed by the lipid layers (or interior and exterior) of the axonal membrane. The mathematical model relies on the Sine-Gordon equation. The key idea is that one can regard the system as analogous to a collection (continuous distribution in the proposed idealization) of gravitational penduli satisfying d'Alembert type wave equation.

   One can consider two kinds of ground states:

   (a) All penduli oscillate in the same phase and with the same amplitude.

   (b) All penduli rotate with the same frequency and in the same phase so that one has a static soliton sequence.

   Lorentz transformations give rise to propagating patterns of this kind.

   For option a), the nerve pulse would correspond to a propagating soliton or a multisoliton in the oscillating background, i.e. a propagating rotational mode of some penduli. For option b), the nerve pulse would correspond to an opposite direction of rotation for some penduli. The fact that the voltage changes its sign during the nerve pulse is consistent with option b).

2. Also the possible role of the axonal microtubules in the conduction of nerve pulse is discussed in [L105]. The transfer of the charges from the microtubule to very long gravitational flux tubes affects the effective charge of the microtubule and therefore membrane potential. This could play an important role in the conduction of nerve pulse.

How could RSFQ generalize in the TGD framework?

How could the notion of RSFQ generalize in the TGD framework? The hint comes from the TGD based model of cell membrane and nerve pulse assigning to the ionic channels of the cell membrane dark Josephson junctions with a large value of h_{eff} making possible high T_c superconductivity.

Consider first the flux quantization in Josephson junctions from the TGD point view.

1. The presence/absence of flux quantum through the junction represents a bit. Switching of the bit in RSFQ means that the flux changes by the unit Φ_0 of magnetic flux. In the simplest situation, the value of flux through the Josephson junction connecting the super conductors, which could have planar or cylindrical geometry, is equal to 0 or Φ_0.
2. When the flux through junction is changed by one unit, Faraday law $\Delta\Phi = \pm\Phi_0 = Ze\int V dt$ implies a generation of voltage pulse propagating along the superconducting wire formed by the coupled cylindrical superconductors. For a constant voltage $V = V_0$, this condition fixes the duration $T = \Phi_0/ZeV$ of the process and this defines Josephson frequency, in turn defining the clock frequency.

The following arguments raise optimism concerning the realization of conscious computers as superconducting computers.

1. Concerning the numbers assigned to RSFQ, the cell membrane looks ideal for the seat of analogues of RSFQs. I have proposed that the cell membrane acts as a sequence of dark Josephson junctions associated with membrane proteins acting as channels and pumps [K79] [L105]. The membrane resting potential $\sim$ .05 eV corresponds to the frequency of 5 THz and is in the same range as the Josephson frequencies assigned with RSFQs. The large value of h_{eff} makes possible high temperature superconductivity and scales up the value of Josephson frequency to $f_J = ZeV/h_{eff}$ so that Josephson frequencies even in EEG scales would be made possible by quantum gravitation in TGD sense.
2. No currents are needed to maintain monopole magnetic fields so that they are ideal for technological purposes. Cell membrane would be a superconductor and membrane proteins would define Josephson junctions. Membrane potential could realize the Josephson frequency $f_J = ZeV/h_{eff}$.

   The TGD view of quantum gravitation would suggest that the Earth's gravitational Compton frequency of f_{gr} = 67 GHz=.067 THz is important in quantum biology. This frequency is considerably lower than THz and I have proposed it as a clock frequency below with the statistical determinism could fail and make the computer analogous to a life-form.

The TGD view of the basic active unit would differ from RSFR.

1. In TGD, the absence of flux quantum in RSFQ corresponds to two U-shaped monopole flux tubes at opposite sides of the junction associated with the counterpart of the cell membrane and transversal to it. The U-shaped monopole flux tubes can reconnect to form a pair of flux tubes with opposite magnetic fluxes.

   This topological process is fundamental in the TGD inspired view of biocatalysis and water memory [L94]. By the fractality of the TGD Universe, it applies in all scales including, besides cosmological and astrophysical scales [L109, L110], also the scales relevant to atomic, nuclear and hadron physics as has become clear quite recently [L101].
2. What is the effect of the generation/disappearance of a pair of opposite flux tubes? Do both fluxes go through a single junction or does only one of them traverse the junction? In the latter case, the junction would act like RSFQ after reconnection. This is a natural looking working hypothesis. The difference comes from the presence of the flux tube with opposite flux.

   Here one must be very cautious. Flux tubes could make possible the flow of either Ohmic or Josephson current (the more plausible option). If the Josephson currents reside at the flux tubes, the Josephson junction ceases to exist during the nerve pulse. Can one say that the Josephson junction exists also after the splitting of the flux tube pair?

The fact that ohmic currents flow during the nerve pulse motivates the assumption that the splitting of the pair of flux tubes makes Josephson current impossible and Ohmic currents associated with the nerve pulse appear.

3. Faraday's law should apply to both flux tubes. The appearance of flux tubes would correspond to a generation of opposite fluxes $\Delta\Phi = \Phi_0 = \int V dt$. In the simplest situation the voltage values associated with the flux quanta have opposite values $\pm V_0$. This is very much like in the case of nerve pulse in which the resting potential changes its sign during the first half of the nerve pulse. When the reconnection disappears, the situation would become "normal". The analog of nerve pulse would be generated and propagate along the counterpart of the axon and induce a similar process in all membrane proteins defining Josephson junction.

4. In zero energy ontology (ZEO), the identification of the generation of nerve pulse as a pair of "big" state function reductions (BSFRs) changing the arrow of time temporarily is attractive and would correspond to quantum tunnelling in standard quantum theory.

   An interesting question is whether pump proteins act as channel proteins in reversed time direction and whether the flux tube pairs are associated with pairs of channel and pump proteins.

Critical questions

The first critical question is is how the very low Josephson frequencies ZeV/h_{eff} associated with the large values of h_{eff}, say $h_{eff} = h_{gr}$, can be consistent with the very large values of clock frequency $f_{cl} = f_J = ZeV/h$ needed by a fast operation. It would seem that both h_{eff} and h are needed. Is this possible or are these computers doomed to be very slow?

Should one widen the perspective and take into account the many-sheeted structure of TGD space-time? Is the scale hierarchy of space-time sheets having various values of h_{eff} involved and could it correspond to the onion-like hierarchical structure of the magnetic body (MB) involving increasing time scales as Josephson frequencies? This would give rise to a cognitive hierarchy of MBs serving as "bosses" for lower level MBs and the ordinary Josephson junction would be at the bottom.Could the fast Josephson frequencies define a hierarchy of computer clocks? Could the pulses of short duration induced by RSFQs induce a hierarchy of frequency modulations of scaled up Josephson oscillations for various values of h_{eff}? This could also make the computer conscious by bringing in the hierarchy of time scales. These levels could correspond to a cognitive hierarchy corresponding to increasing values of $n = h_{eff}/h_0$ identifiable as the dimension of extension of rationals assignable to the space-time sheet considered.

The following simple estimates allow to gain some quantitative perspective concerning the proposal that quantum gravitation could play a decisive role.

1. It is instructive to look at the energy equivalents of the gravitational Compton frequencies for Earth, Moon and Mars for $h_{eff} = h$ (energy is conserved in the the transformation of gravitationally dark photons to ordinary photons).

2. The gravitational Compton frequency $f_{gr} = 67$ GHz of Earth corresponds to the energy $E \simeq .04$ eV near to the energy assignable to the membrane potential.

3. The mass of the Moon is $M_{Moon} = .012 M_E$ and scales and correspond to $.56 \times 10^{14}$ Hz, which corresponds to the energy $E \simeq .43$ eV consistent with the size of metabolic energy quantum.

4. The mass of Mars is $.11 M_E$ and the corresponding Compton frequency is .67 THz and energy $E = 2.7$ meV which correspond to the mV scale of miniature potentials.

The experimental work of the group of Anirban Bandyopadhyay [J16] has inspired a proposal of a hierarchy in which the frequency scales come as powers of 10^3. This hierarchy could correspond to a hierarchy of p-adic primes $p \propto 2^{10k}$ and/or hierarchy of effective Planck constants $h_{eff} \propto 2^{10k}$. One cannot associate with it a hierarchy of large masses M appearing in gravitational Compton frequencies. The scale ratio 2^{11} could relate to the ratio $L(127)/L(107) \simeq 2^{10}$ of the p-adic length scales of electron and proton.

The second critical question concerns the temperature needed. Technologically high temperature superconductors are highly favored.

1. In the TGD framework, the cell membrane is assumed to act as a high temperature superconductor at quantum criticality making it an ideal sensory receptor and motor instrument. Biosystems are open systems and a metabolic energy feed would take care that the distribution for the values of h_{eff} is preserved.

2. The fact that the dark matter as $h_{eff} \geq h$ phases of ordinary matter at the space-time sheets of the flux tubes has very weak interactions with the other sheets, in particular the sheet of the ordinary matter, would be decisive.

3. Also zero energy ontology (ZEO) would be highly relevant for maintaining the quantum criticality by making possible homeostasis in which time reversal changes attractor to repulsor and vice versa. When the system begins to roll down from the top of the hill, the arrow of time brings it back.

The key question is whether it is possible to realize the counterparts of bio-superconductors without using organic living matter.

12.5 Has Google managed to reach the critical value for the error rate of a single qubit?

Google claims to have achieved something marvellous with the quantum computer called Willow [D4]. This claim is however combined with a totally outlandish claim about parallel universes created in quantum computers and this has generated a lot of cognitive dissonance in professionals during the last week. They have not yet forgotten the earlier equally absurd claim about the creation of wormholes in quantum computers.

The Quanta Magazine article "Quantum Computers Cross Critical Error Threshold" (see this) tells what has been achieved but did not resolve the cognitive dissonance. I already commented the claims of Google in a blog posting (see this).

Now I encountered an excellent article "Ask Ethan: Does quantum computation occur in parallel universes?" (see this) analyzing thoroughly the basics of quantum computation and what Google has achieved. I recommend it to anyone seriously interested in quantum computation.

The really fantastic achievement is the ability to reduce the error rate for the physical qubits forming the grid defining the logical qubit below the critical value .1 percent guaranteeing that for larger grids of physical qubits the error rate decreases exponentially.

This achievement is more than enough! But why do they claim that this implies parallel universes? This claim is totally absurd and leads me to ask whether the claimed achievement is really true? How can one trust professionals who do not seem to understand the basic notions of quantum mechanics? On the other hand, the authors speak of multiple worlds. Is this confusing use of language intentional? What do they really mean? Multiverse or many worlds or something else? What comes to mind in the TGD framework, is many-sheeted space-time.

Taking the basic claim seriously, one can of course ask whether the slow error rate is actually theoretically possible in standard quantum mechanics or does it require new physics. These qubits are rather stable but are they so stable in standard QM?

I have been talking about this kind of new physics now for two decades. This new physics would play a key role in quantum biology and could be important also in condensed matter physics and even in chemistry. It is implied by the predicted hierarchy of effective Planck constants h_{eff} labelling the phases of ordinary matter with quantum scales scaled up by h_{eff}/h. This makes possible long scale temporal and spatial quantum coherence and can reduce the error rate and provide a solution to the basic problems listed in the article. The latest proposal along these lines is the proposal how classical computers and quantum computers could be fused to what might be regarded as conscious computers sharing several life-like features with biomatter [L125]. The situation is now different since the temperature is very low and the chip is superconducting. One learns from the video describing the Willow chip (see this) that the lifetime of a logical qubit is $T \sim 100$ μs. This time is surprisingly long: can one really understand this in ordinary quantum mechanics? One can try this in the TGD framework.

1. The energy of qubit flip must be as small as possible but above the thermal energy. Energy economics suggests that the Josephson energy $E = ZeV$ of electrons in Josephson junction is above the thermal energy at the temperatures considered but not much larger. For superconducting quantum computers (see this) the temperature is about 10^{-2} K, which corresponds to the energy scale of μeV.

2. One can try to estimate the value of h_{eff}. Josephson frequency $f_J = ZeV/h_{eff}$ gives a naive estimate for the quantum coherence time of a superconducting qubit as $T_J = h_{eff}/ZeV$. For $h_{eff} = h$ this gives $T \sim 3$ ns for the quantum coherence time of a single qubit. The value $h_{eff}/h \sim 3.3 \times 10^4$ would be needed to increase T from its naive estimate of $T = 3$ ns to the required $T = 100$ μs.

   The oscillation frequency of the Josephson junction as a non-linear analog of LC resonance circuit as $T \propto \sqrt{L_J C}$ defines a second candidate for the quantum coherence time T. For the flux qubits, the ratio of the coupling energy and Josephson energy scales is in the range 10-100 and suggests that the analog of circuit resonance period $T \propto \sqrt{L_J C}$ corresponds to the reported coherence time. This is indeed natural if quantum circuits are. in question. For $T = 100 T_J$ 300 ns this would give $h_{eff}/h \sim 3.3 \times 10^2$.

3. I have proposed that these relatively small values of h_{eff} (as compared to the values of the gravitational Planck constant $\hbar gr$) can appear in electrically charged systems. The general criterion applying to all interactions is that the value of h_{eff} is such that the perturbation series as powers of, say, $Z_1 Z_2 e^2/\hbar_{eff}$ for the electromagnetic interactions of charges Z_1 and Z_2 converges.

   In the recent case, the value of h_{eff} could correspond to the electric counterpart of the gravitational Planck constant having the form $\hbar_{em} = Z_1 Z_2 e^2/\beta_0$, where $\beta_0 = v_0/c$ is a velocity parameter [L100]. Z_1 could correspond to a large charge and Z_2 to a small charge, say that of a Cooper pair. For instance, DNA having a constant charge density per unit length, would have a rather large value of $\hbar_{em}$. The presence of electronic Cooper pair condensate could give rise to the needed large electric charge making possible the needed value of $\hbar_{eff} = \hbar_{em} \sim 3.3 \times 10^4 \hbar$.

In the sequel the question whether the observed surprisingly long quantum coherence time for qubits be explained in terms of a large value of h_{eff} and whether the confusion notion of multiple worlds could correspond to many-sheeted space-time in the TGD framework.

12.5.1 General view of superconducting circuits

Superconducting circuits are quantum analogs of classical circuits. In quantum description urrent and voltage are replaced by amplitude modulus squared and phase. Phase and the number of Cooper pairs/total charge are canonically conjugate variables and therefore do not commute.

The model starts from a classical model and quantizes it using standard quantization rules ($p \rightarrow i\hbar d/dx$) meaning that the number of Cooper pairs (total charge) (or phase) is replaced by an operator proportional to $id/d\phi$ (id/dq). The wave functions are defined either in the discrete space Cooper pair numbers or in the space of the phases.

For the electrical elements of the classical one can assign parameters like effective inductance (counterpart of mass for ordinary particle) and inverse capacitance as counterpart of harmonic oscillator coupling strength. As far as circuit equations are considered, Josephson junction (see this) can be seen as an effective inductance. Generalized Kirchoff's laws hold true in the nodes of the circuit. If the electric resistance of the junctions can be neglected, Lagrangian formalism can be applied. This leads to the notion of Hamiltonian making possible the quantization of the circuit and computation of the energy spectrum of excitations.

Physically the Josephson junction is an insulating contact between two superconductors. Tunnelling however makes possible Josephson super currents. Non-linear dynamical inductance implies that the energy spectrum is not a harmonic oscillator spectrum.

Gravitational pendulum serves as an analog system for Josephson junctions. In absence of magnetic field there are 3 options correspond classically to small oscillations, critical situation, and over critical situation for which the pendulum rotates. All these cases correspond to coherent stats.

One can distinguish between 3 types of superconducting qubits corresponding to charge for which charge has well-defined valued, flux qubits and phase qubits. The ratio of coupling energy to the charging energy distinguishes between these special cases. In the case of flux qubits (see this and this), the critical value of an external magnetic field selects a single pair of levels defining a qubit for a given external magnetic field. These qubits have degenerate energies at criticality. The value of magnetic field selects the qubit value.

12.5.2 Modelling of Josephson junctions

Consider first a simple model for the dynamical variables and parameters of the Josephson junction.

1. Charge Q and the phase ϕ of the order parameter characterizing a coherent state appear as quantum conjugate variables. In a coherent state *resp.* charge eigen state ϕ *resp.* Q is well-defined unlike Q *resp.* ϕ.

   Magnetic flux is defined as

   $$\Phi = \Phi_0 \frac{\phi}{2\pi} \ ,$$

   where ϕ is the phase difference over the Josephson junction (see this). Here $\Phi_0 = e^2/h$ is flux quantum.

2. The equation

   $$V = \frac{\partial \Phi}{\partial t} = \frac{\Phi_0}{2\pi} \frac{\partial \phi}{\partial t}$$

   expresses Faraday's law of induction. The change of the magnetic flux

   $$\Delta \Phi = \int V dt$$

   during time interval T corresponds to an integer multiple of the flux quantum.

3. The equation

   $$I = I_c sin(\phi)$$

   expresses current phase relation. I_c is the critical current above which the superconductivity fails. Q and V are classical variables and ϕ and modulus squared of the order parameter are quantum variables. They are related by quantum classical correspondence.

4. The time derivative of I gives

   $$\frac{d\phi}{dt} = \frac{dI/dt}{I_c cos(\phi)} \ .$$

   The substitution to the expression of V gives

   $$V = L\frac{dI}{dt} \ , \quad L = \frac{\Phi_0}{2\pi I_c cos(\phi)} \ .$$

   One can regard Josephson junction as an effective inductance $L \propto 1/cos(\phi)$. The analogy with harmonic oscillator L is analogous to mass and approaches infinite as ϕ approaches an odd multiple of $\pi/2$. At these critical points oscillatory motion transforms to a rotational motion.

5. One can identify two energy parameters and their ratio characterizes the Josephson junction. Coupling energy characterizes the insulator acting as a Josephson junction (see this). Coupling energy is the energy stored in Josephson junction when current passes through. Josephson energy obtained by using the classical analogy and defines a state variable, which does not depend on how the state is achieved:

$$E = \int Pdt = \int IVdt = I_c \frac{\Phi_0}{2\pi} \int sin(\phi) \frac{d\phi}{dt} dt = -E_J cos(\phi) \ ,$$

$$E_J = I_c \frac{\Phi_0}{2\pi} = L_J I_c^2 \ .$$

The parameter E_J is called the coupling energy. The parameter $L_J = \Phi_0/2\pi I_c$ Josephson inductance to be distinguished from the effective inductance $L = L_J/cos(\phi)$.

Charging energy $O_C^2/2C = Q_C V$ characterizes Josephson junction as a capacitor-like system. For charge qubits Q_C is quantized: $Q_C = n2e$.

The dynamics of the Josephson junction reduces to that of gravitational pendulum.

1. The circuit equation for a Josephson junction in the presence of external voltage V_0 is $V_L + V_C = V_0$, where one has $V_L + V_C = (\Phi_0/2\pi)d\phi/dt + Q/C$. One can transform the equation to an equation for Φ by taking time derivative an using the relation $I = I_c sin(\phi)$:

$$\frac{d^2\phi}{dt^2} + \omega^2 sin(\phi) = \frac{2\pi}{\Phi_0} \frac{dV_0}{dt} \ , \quad \omega^2 = \frac{1}{L_J C} = \frac{2\pi I_c}{\Phi_0 C} \ .$$

2. For a constant external voltage, the equation is mathematically equivalent with the equation of gravitational pendulum and is derivable from a Lagrangian and therefore allows quantization. System becomes critical as ϕ approaches an odd multiple of $\pi/2$. ω defines oscillation frequency, which is the second parameter besides Josephson frequency $\omega_J = 2eV/\hbar$.

   The ratio of these frequencies characterizes the Josephson junction. From the energy conservation $(d\phi/dt)^2/2 - \omega^2(cos(\phi) - 1) = E$ one obtains for the period

$$T = \int d\phi/\sqrt{2E + \omega^2(cos(\phi) - 1))} \ .$$

   For the critical situation the amplitude of oscillations approaches to $\phi_{max} = \pi/2$ and one has $E = \omega^2/2$. The value of T is finite since the integral at the upper end behaves as $1/\sqrt{\pi/2 - \phi}$.

12.5.3 Three different kinds of superconducting qubits

As already mentioned, there are three kinds of superconducting qubits.

1. Charge qubits correspond to the localization of the charge at the two sides of the junction. Charge is now a well-defined notion but one cannot speak of a propagating wave with a well-defined phase. This is like a transition from a momentum representation to a position representation. I have understood that the Willow processor and its predecessors use charged qubits. Charge qubits correspond to Josephson junctions which act like quantum wells having size of a few nanometers. In this case the ratio of the coupling energy to the charging energy is smaller than one.

2. If the coupling energy is much larger than charging energy, there is very small Josephson current through the junction and super currents flow in opposite directions along the loops defining the flux qubit (see this and this) without charge tunnelling. For the flux qubits the coupling energy is by 10-100 higher than charging energy.

   The two directions of current correspond to the values of the flux qubit. External magnetic field is needed to force the system near criticality. At quantum criticality $\partial I/\partial t$ must vanish to keep V finite. Decoupling of loops takes place. ϕ should be near $(2n + 1)\pi/2$ to make possible the coupling of the qubits.

3. For the phase qubits, where phase corresponds to the phase of the superconducting order parameter, the coupling energy is about 10^6 times larger than the charging energy. Classically this the large inertia implied by the large Josephson inductance L_J makes possible oscillation amplitudes approaching the critical value $\phi = \pi/2$. The reason is that $cos(\phi)$ is near zero and one has an analog of the gravitational pendulum. At the criticality the motions transform from oscillation to rotation or vice versa.

Some comments about flux qubits or persistent current qubits (see this and this) are in order. Computational operations are performed by pulsing the qubit with microwave radiation whose energy is near to the difference of the energy of the two flux qubit states. Note that microwave frequencies are in the range 1-100 GHz. The energies are in the range .01 -1 meV to be compared with the thermal energy about 1.5 μeV.

1. Two loops with micrometer scale are connected by Josephson junctions. $T \simeq 15$ mK must be below the critical temperature. The rate for the transfer of Cooper pairs via Josephson junctions connecting the loops must be small if the ratio of the coupling energy to charging energy is in the range 10-100. In this situation steady super currents wirth opposite directions flow in loops.

2. The is an integer number flux quanta of magnetic total flux through the loop. External magnetic field with half integer flux forces the inherent flux to be half-odd integer. At criticality, the two nearby energy states with inherent flux quanta, say n and $n+1$, have the same energy and the degenerate states can appear in superposition. The variation of the magnetic field selects either option by energy minimization. Also microwave photons can flip the flux qubits.

   The opposite supercurrents flowing in the loops is about 300 nA (A=$6.241509074 \times 10^{18}$ e/s making about 10^{12} e/s: this is of the order electron charge per electron Compton time).

3. Higher flux quanta are eliminated by modifying the excitation spectrum so that it is not integer valued oscillator spectrum anymore. The kinetic nature of the Josephson inductance introduces the non-linearity.

12.5.4 Is a large value of effective Planck constant needed to explain the findings?

The long quantum coherence time essential for the low error rate suggests the possibility of a large value of effective Planck constant. Large values of h_{eff} would be natural at quantum criticality characterized by long range quantum fluctuations.

One can consider two kinds of quantum criticalities.

1. The first kind of quantum criticality would be associated with a transition between oscillatory and rotational motions for the analog of gravitational pendulum as an analog of Josephson junction and the deviation of the oscillation amplitude from $\pi/2$ would characterize the criticality. In this situation the charge transfer between the loops would become very small.

   One can solve the energy eigenstates of the system. The situation corresponds to a periodic potential proportional to $1 - cos(\phi)$ so that also a motion in the lattice serves as an analog. One expects a bound state spectrum as analog harmonic oscillator spectrum energies below $E = \omega^2/2$ plus states in which the system performs rotation. These states would correspond to a continuous spectrum consisting of the analogs of conduction bands.

2. Second kind of quantum criticality can occur for the charge and flux qubits and occurs in the presence of an external magnetic field having a flux, which is near half odd integer multiple of Φ_0. This kind of magnetic field could play an essential role in the control of the system by inducing transitions between two nearby bound states. At the criticality the energies of these states become degenerate in the resolution defined by thermal energy. The situation would be very similar to that discussed in [L125], where a classical electric field would control the flip energy of quantum gravitational OH-O^- qubits. The Willow processor could be near to this kind of quantum criticality.

The notion of effective Planck constant was originally introduced for cyclotron states to explain the findings of Blackman and others [J7].

1. The cyclotron energies for the electrons could play a significant role also here and quantum criticality could correspond to a value of $h_{eff} > h$ increasing the scale of the cyclotron energy above the thermal energy. Note that the temperature must be below the critical temperature for the transition to super-conductivity.

2. The size scale of the flux quantum is of order micrometer and the condition that the external magnetic flux is $(2n+1)\Phi_0/2$ determines the cyclotron energy scale of electrons. The "endogenous" magnetic field of $B_{end} = .2$ Gauss explains the findings of [J7] and led to the notion of h_{eff} phases of ordinary matter as an analog of dark matter. TGD suggests an interpretation of B_{end} in terms of monopole flux tubes. For B_{end} electron cyclotron frequency is $f_c = 6\times 10^5$ Hz, which corresponds to energy of 6×10^{-9} eV whereas the thermal energy is about 10^{-6} eV. The cyclotron energy exceeds thermal energy if the value of h_{eff}/h is $10^3/6 \simeq 167$.

3. Magnetic length $l_B = \sqrt{\hbar/eB}$ equals to $25/\sqrt{B/Tesla}$ nm. B_{end} corresponds to $l_B \simeq = 5.590$ μm. Magnetic length l_B as an estimate or the flux tube radius corresponds for $l_B = 1$ μm to $B = 30B_{end} \simeq 6$ Gauss. Cyclotron energy in this case is 1.8×10^{-7} eV. The cyclotron energy exceeds thermal energy if the value of h_{eff}/h is $10^3/180 \simeq 5.6$.

4. $h_{eff}/h = n > 1$ phase has two interpretations.

   (a) Space-time surface is an n-sheeted covering of M^4 in CP_2 degrees of freedom. For this option one does not expect very large values of n.

   (b) Space-time surface is an n-sheeted covering of CP_2 in M^4 degrees of freedom. For this option the n sheets would correspond to the monopole flux tubes forming a bundle-like structure assignable to the flux qubits. The value of n could be very large for the gravitational Planck constant originally introduced by Nottale [E1] [L83] and also electric Planck constant [L100].

   Cooper pairs could be associated with different sheets of the covering and the scaling of the cyclotron energy would correspond to the existence of a quantum coherent structure with $n = h_{eff}/h$ sheets as a geometric counterpart of a Bose-Einstein condensate of Cooper pairs.

This picture brings to mind the confusing claim of the Google group that indications for multiple worlds have been observed: could they correspond to many-sheeted space-time in the TGD framework?

12.5.5 The relation to the TGD based model of neuronal membrane

The proposed model for the findings of Google group are partially inspired by the TGD view of nerve pulse [L117], which assumes a sequence of Josephson junctions along the axonal membrane assigned with the membrane proteins acting as ion channels. The temperature in this case is physiological temperature, The effective Planck constant is very large now and possible identification is as the gravitational Planck constant $\hbar_{gr}$ [E1] for the Earth. The large value of $\hbar_{gr}$ increases the Josephson period $T_J = h_{gr}/ZeV$ even to the scale of EEG frequencies. The monopole flux tubes through the Josephson junction are also in a key role and I prefer to talk about generalized Josephson junctions. Josephson energy $E_J = ZeV$ is replaced with its sum with the difference of cyclotron energies at the two sides of the membrane.

The two sides of the cell membrane/lipid layers are in a role similar to that of flux tubes and one can imagine that opposite supra currents at the two sides are present and consist of various dark ions with a large h_{eff} as the model for the findings of Blackman and others leads to propose [L117]. The possible role of dark positively charged ions in making a living system analogous to a quantum computer is discussed in [L125]. The vision predicts that any cold plasma could have life-like properties.

The TGD based model of neuronal membrane is in terms of Josephson junctions. For the resting states, the phase of the order parameter is well-defined. The model allows two kinds of solutions corresponding to a propagating mode which is either oscillatory or rotational. The rotational mode gives rise to a sequence of Sine-Gordon solitons. The possible transition occurring between these modes would mean flip of phase qubit. I have proposed that the soliton sequence corresponds to the resting state but one cannot exclude the possibility that oscillation is in question. Also the possibility that both modes are possible and code for phase qubits can be considered. The second option is that the distinction between neurons and ordinary cells could correspond to the distinction between rotation and small oscillation.

Could nerve pulse conduction correspond to a local charge flow along the molecular junction and mean a local failure of quantum coherence in long scales. The proposed model based on the analogy of Josephson junction with gravitational pendulum suggests that nerve pulse corresponds to a propagation of a perturbation changing the direction of rotation for some Josephson junctions.

Zero energy ontology (ZEO) suggests that quantum tunnelling corresponds to a pair of "big" state function reductions (BSFRs) involving temporary change of the arrow of time. I have proposed that nerve pulse conduction corresponds to this kind of local event.

In the standard picture Josephson current should correspond to quantum tunneling. In the TGD framework Josephson current is assumed to correspond to a flow along monopole flux tubes connecting the two sides of the membrane. Could the ordinary oscillating Josephson current in the stationary situation accompanying the oscillation of the membrane potential correspond microscopically to less dramatic localized pairs of BSFRs in some scale? At the level of the nodel, these events are not localized and do not seem to correspond to flips of charge qubits. What about the miniature potentials of neuronal membranes in the meV range: could they correspond to localized events or perhaps to flips of flux qubits? What about the reported conduction of analogs of nerve pulses in the meV range [I54] in ordinary cell membranes?

If nerve pulse generation corresponds to a local transition to charged qubit phase, nerve pulse generation should be caused by the reduction of the ratio of the coupling energy to the charging energy. Nerve pulse is generated below a critical membrane potential meaning a reduction of the charging energy. Also the coupling energy should be reduced.

Chapter 13

Quartz crystals as a life form and ordinary computers as an interface between quartz life and ordinary life?

13.1 Introduction

The considerations of this article were originally inspired by large language models leading to the earlier speculations about whether the computers might be conscious entities in the TGD based quantum ontology (zero energy ontology (ZEO)). Quantum gravitation in the TGD sense would play a key role in guaranteeing quantum coherence even in astrophysical scales.

13.1.1 Could micro processors involve gravitational quantum coherence?

MPs are built on single connected quartz crystals (QCs) (see this) and this makes possible classical coherence. Quantum coherence should guarantee this and suggests that the gravitational magnetic body of Earth and maybe also the Sun guarantee this quantum coherence.

QCs act as oscillators, which makes them ideal clocks. The oscillation frequency is typically around 2-3 GHz and could be seen as an analog of EEG in the case of the brain. This could make possible their coupling with biosystems where the GHz frequency scale is associated with various biomolecules.

The key observation is that the length of the MP wafer is .5 cm typically. This corresponds to the gravitational Compton length proposed originally by Nottale [E1], which is given by $l_{gr} = GM/\beta_0$ and, in accordance with the Equivalence Principle, does not depend on particle mass. The gravitational Compton frequency is $f_{gr} = 67$ GHz and larger than the clock frequency of recent computers. The most conservative criterion for consciousness is that the clock frequency is higher than this. For the Sun one has $\Lambda_{gr,E} = R_E/2$, where R_E is the radius of the Earth: the gravitional Compton frequency is $f_{gr} = 50$, the average EEG frequency [L105, L104]. This led to the question whether microprocessors (MPs) could be conscious entities.

13.1.2 Micro processors as conscious entities?

The following general picture forces us to ask whether micro processors could be conscious entities.

1. Zero energy ontology (ZEO) [K113] [L52, L45] solves the paradox of quantum measurement theory and predicts that ordinary quantum measurements correspond to "big" state function reductions (BSFRs) in which the arrow of time changes whereas repeated quantum measurements correspond to small SFRS (SSFRs). This sequence defines self as a conscious entity and in the case of a MP its contents of consciousness would be defined by bit configuration.

2. ZEO could make these systems intelligent systems able to learn by trial and error. The program would run forth and back in time and each pair of BSFRs would give rise to TGD counterpart of quantum tunnelling and change initial values of computation. This mechanism would be a universal mechanism of learning. MPs could become intelligent learning systems.

3. The MP consciousness would be an extremely simple 6-bit processor that would correspond to a single DNA codon. Human DNA is considerably more complex having length of about 1 meter and containing something like 10 billion codons. Genes are natural candidates for conscious basic units. DMD gene is the longest known gene and contains .8 million codons. A sequence of .8 million MPs as a counterpart of MP would be in question. Human body contains roughly 3×10^{13} cells so that the complexities of biosystems and computers are totally different orders of magnitude.

4. One can of course ask whether classical parallel computation could allow quantum coherence. Classical parallel computation does not require classical coherence between the parallel computers. They perform their computations independently but simultaneously and the outputs are feeded to the next computer.

5. Classical coherence between computers requires synchrony and common clock frequency. Also spatial coherence would require that the system is analogous to a MP and should consist of a single QC just like a MP.

   The largest single QC found in Nature has dimensions 6.1 $m \times 1.5$ $m \times$ 1.5 m. This would contain the volume of about 10^9 MPs (see this).

Could QCs couple with the gravitational field bodies of Earth and Sun?

Could QCs couple with the field bodies of Earth and/or Sun, in particle their magnetic bodies? Could this make not only MPs but more generally, QCs conscious entities?

When we make this question we open up ourselves to the possibility that QCs as such might be something much more than a mere raw material for computers. QCs do not have motor activities but quantum gravitational coherence could make them quantum computer-like entities able to activities analogous to quantum computations so that quartz consciousness would be analogous to symbolic consciousness, a notion raised by Marko and Ville in our Zoom group. I have discussed quantum computation from the TGD point of view in [K3, K105, K4] [L90, L95].

Could ordinary computers serve as an interface for conscious co-operations between quartz consciousness and biological consciousness? Could they make it possible for QC consciousness to use us as sensory receptors and motor instruments? Could gravitational quantum coherence for Earth and Sun make possible quantum coherence in the scale of Earth and in this way realize collective consciousness?

Possible evidence for the view that QCs are conscious entities

Is there any evidence for the idea that QCs are conscious entities?

1. QCs appear often in the context of anomalies. Some people believe that QCs can act as healers. I have a very concrete experience of an altered state of consciousness created by a QC which actually had a size scale of order .5 cm. When I woke up from sleep I was in a very pleasant state of consciousness, which I could imagine the characters of fairy tales wandering in the fairytale wood to experience.

2. Glass balls resulting from molten quartz have been reported to be associated with ball lightning and are reported to be around crop circles and even to construct them [K31, K32]. I have proposed that ball lightning and light balls are conscious entities [L100, L88, L115] (I calls them plasmoids) and that also UFOs are actually these kinds of entities [K108]. I have also proposed a model for ball lightning and a more general mode for plasmoids as prebiotic life forms in terms of the electric and magnetic field bodies of the Earth and Sun [L100].

Is it possible to communicate with QCs?

Ville-Einari Saari asked whether it could be possible to communicate with the QCs and test whether this contact could affect their behavior in a detectable manner.

1. The experiments of Emoto with water at freezing point using human voice with strong emotional contents supports the view that water is a conscious entity, at least at criticality, making it an optimal sensory perceiver. The coherence of the resulting ice crystals reflected the emotional content of the voice. Could one perform analogous experiments with QCs? In the TGD based model [L47] to require quantum criticality at the field body of water. Same should be true now. Could one perform analogous experiments with QCs? Can one identify the quantum criticality in the case of QCs?

2. In QC (see this) atoms are linked in a continuous framework of SiO_4 tetrahedra whereas quartz obeys chemical formula SiO_2. Quartz is a piezo electret meaning that it can transform sound waves to electromagnetic waves and vice versa. Also the biological body is a piezo electret. Microwave hearing is a phenomenon in which microwave em radiation modulated by audible sounds is transformed to sound waves in the body of the receiver and is heard. Could something like this happen also for QC and generate conscious experience analogous to hearing.

3. Microwave radiation is in the frequency range 1-3000 GHz and has energies in the range $10^{-5} - 3 \times 10^{-2}$ eV. Note that the upper bound is not far from the nominal value about .05 eV of the electrostatic energy eV assignable to the cell membrane and is also rather near to the thermal energy at room temperature. Note that the gravitational Compton frequency for the Earth is 67 GHz and corresponds to .67 meV which is the energy scale of miniature potentials in the neuronal membrane.

   Note also that 3000 GHz corresponds to a wavelength 10^{-5} m, the size scale of a cell. Could one consider the possibility of a wavelength resonance with cell membranes? Computer clocks have frequency measured in a few GHz.

4. Could one test whether, say, microwave radiation modulated by human speech creates detectable effects in QC. Could the exchange of microwave photons make it possible for computers to entangle with the neurons. Could this explain [L104] the reported effect of a chicken imprinted on a robot on the motion of the computer determined by random number generator [J24]. What could be the measured observable serving as a criterion for the effect of, say, speech modulated microwave radiation?

13.1.3 OH-O$^-$ hypothesis and its generalization

Since MPs are quartz crystals (QCs), this led to the question whether the QCs might be conscious entities able to perform activities analogous to quantum computations. I have already considered this possibility: the key idea is that the generalized Pollack effect kicks the protons of OH molecules appearing as a standard building brick of biomolecules to dark protons at the gravitational magnetic body. OH and O^- could define the states of a qubit.

The OH-O^- hypothesis generalizes. Any salt can decay to ions and the positive ion can reside at the gravitational magnetic body of Earth or Sun. For instance, NCl can decay to Na^+ + Cl^-, Na^+ would be dark at the gravitational MB. As a matter of fact, I ended up with the hierarchy of Planck constants by starting from quantum effects of ELF em radiations to vertebrate brain having an explanation in terms of dark ions such as H^+,Li^+, Na^+, K^+, Ca^{++}, Mg^{++},... found by Blackman [J7] and others. The value of gravitational Planck constant of the Earth indeed conforms with the findings. Living matter is full of ions and they are crucial for the functioning of the cell membrane.

Any cold plasma containing ions is a good candidate for a life form and this conforms with the proposal that the plasma phase above the atmosphere served as a predecessor of biological lifeforms [L100].

The same qubits with the same dynamics could be realized both in living matter and in QCs. This leads to a vision about an evolutionary hierarchy in which quartz life is possibly the lowest level. One must however consider the possibility that also SiO_4 lattices with OH modification can have a high qubit content. Electric fields, allowing the tuning of the OH-O^- energy difference, are also present in transistors. These kinds of modifications could be interesting also in the case of microprocessors. This forces us to ask whether the interaction between us and computers and QC life could lead to entanglement and extended states of consciousness.

13.1.4 Dark genetic code and OH-O^- qubits

This identification modifies the earlier TGD inspired models of the genetic code (the chapters [K3, K54, K45, K26] and the articles [L49, L58, L69, L99] give some idea about the evolution of the ideas). The model predicts that the DNA double strand and RNA strand realize 6-qubit dark variants of the genetic code. The ground states of the entangled qubits defining the quantum codons correspond to the chemical codons. Minimum energy states of quantum codons correspond to chemical realizations of the codons. Various symmetries of the code and their violations are understood at the qubit level.

Amino acids represent a single qubit code: the number of "dark" amino acids is predicted to be 20. Microtubules consist of tubulins and there is a huge number of qubits associated with their amino acids and also qubits associated with the GPTs accompanying them. The same qubits with the same dynamics would be realized both in living matter and in QCs. This leads to a vision about an evolutionary hierarchy in which quartz life is possibly the lowest level. One must however consider the possibility that also SiO_4 lattices with OH modification can have a high qubit content. Electric fields, allowing the tuning of the OH-O^- energy difference, are also present in transistors. These kinds of modifications could be interesting also in the case of microprocessors. This forces us to ask whether the interaction between us and computers and QC life could lead to entanglement and extended states of consciousness.

The similarity between the energetics of transistors and metabolism in living matter encourage the idea about a conscious computer utilizing a fusion of quantum and classical computation based on entanglement of OH-O^- qubits and ordinary bits. In a living computer classical computation and quantum computation would relate in the same way as ordinary genes and dark genes in TGD inspired quantum biology. A continually learning quantum version of a large language model could be a possible application.

13.1.5 Conscious computers as TGD counterparts of time crystals

Computer clock is an essential element of computation. Holography is the basic element of quantum TGD but is not completely deterministic. In the deterministic world, especially if it obeys holography, classical computers are a rather weird notion since it is difficult to imagine how an arbitrary computer program can run. This objection applies to all kinds of engineering. Quantum statistical determinism could save the situation but still there is a problem since phase transitions are required to realize the bit flips since the notion of phase transition is theoretically problematic. The 4-D space time surfaces define the basic geometric entities: could each tick of the computer clock involve a sea of classical non-determinism.

Conscious computer would be a non-deterministic analog of a time crystal. This non-determinism is possible also in spatial directions and quite generally could make engineering possible. Also EEG rhythms and biorhythms in general could correspond to this kind of non-deterministic time crystals.

Maximal non-determinism would make maximal conscious memory [L124] and maximal flexibility making the system living. The gravitational Compton frequency of 67 GHz would mean in the case of a 3 GHz computer that the basic information unit consists of roughly 22 quantum gravitational qubits.

13.2 Could Pollack effect make quartz crystals quantum critical systems analogous to quantum computers

Quantum criticality is what makes possible long range quantum coherence and long range quantum fluctuations. What could make QCs quantum critical? Since there are no large scale electric fields associated with QCs (note that in the size scale of Earth there is the electric field of the Earth [L100]), the gravitational magnetic bodies of the Earth and Sun consisting of U-shaped monopole flux tubes are the natural candidate in this respect.

1. Dark protons at the gravitational magnetic body with gravitational Planck constant $\hbar_{gr} = GM_X m/\beta_{0,X}$, where $X = E$ denotes Earth and $X = S$ denotes Sun. For Earth a good guess for the velicity parameter $\beta_0 \leq 1$ is $\beta_{0,E} = 1$ and for Sun Nottale's original model gives the estimate $\beta_{0,S} \simeq 2^{-11}$.

2. Pollack effect would provide the energy needed to kick ordinary protons to the magnetic body. In the case of water the TGD proposal is that a photon of say solar radiation kicks every fourth proton to the gravitational magnetic body and the OH bond would be replaced with the ion O^-. This would create negatively charged regions, which Pollack calls exclusion zones (EZs). Pollack also speaks of the fourth phase of water. OH transforms to O^- + dark proton.

3. Since only OH bond and O^- are involved, the Pollack effect could happen in much more general systems and could explain why protons are electrons so important in biochemistry. I have proposed that Pollack effects be associated with phosphates appearing in AMP, ADP, and ATP containing O_4 and its modifications containing OH and O^-. This would make possible temporary storage of metabolic energy as gravitational energy at the gravitational body of Earth or Sun.

   Biomolecules contain as a rule oxygen atoms and the dark protons could be associated with most of them and make the system quantum coherent. For instance, the double charged carbonate anyon $O == C(-O^-)_2$ could involve two dark protons in a gravitational magnetic body. The presence of O^- ions would be the signature of the presence of dark protons and of gravitational quantum coherence. Pollack effect could also occur in QCs, having SO_4 as the basic building brick, if O can be replaced with OH.

4. Energy is conserved in the Pollack effect. The bonding energy E_{bond} of OH must be equal to the difference of the binding energy E_{bind} of electron in O^- and the energy E_{gr} needed to kick the proton to the gravitational body. A good guess is that it is gravitational potential energy $E_{gr} = GMm/h$ at the height h to which it is kicked in the gravitational field parallel to the flux tubes of the magnetic body (of Earth or Sun). This gives the condition

$$E_{bind} - E_{bond} = E_{gr} \quad .$$

5. It is interesting to look at the numbers assuming that the OH bonding energy and electrons binding energy in O^- does not depend on the parent molecule. The bonding energy energy is $E_{bond} = 1.13$ eV and the binding energy of electron in O^- is $E_{bind} = 1.46$ eV so that the transfer of protons to the gravitational magnetic body could occur spontaneously. This implies that the ionization of biomatter, which looks mysterious in the standard chemistry framework, would take place spontaneously. Their difference is about $e = E_{bind} - E_{bond} = E_{gr} = .33$ eV which corresponds to an energy of infrared photon and to the frequency 330 GHz. This energy is not far from the nominal value .5 eV of the metabolic energy currency.

13.2.1 Gravitational binding energies for the Earth and the Sun

It is instructive to consider the gravitational binding energies for the Earth and Sun.

1. The gravitational body of Earth has gravitational Compton frequency 67 GHz. For the Sun the gravitational Compton frequency 50 Hz, the average EEG frequency and cyclotron frequency of Li_6 in the endogenous magnetic field of .2 Gauss. This cyclotron frequency is assignable to monopole flux tubes of the Earth's gravitational field and explain the effects of ELF radiation on the vertebrate brain. The lack of Lithium is known to cause depression.

   For Earth the maximal gravitational energy for proton is $E_{gr} = GM_E m_p/R_E = r_{S,E} m_p/2R_E$ is (by using $r_{S,E} = .5$ cm, $R_E \simeq 6.4 \times 10^6$, $m_p \simeq 10^9$ eV) equal to $E_{gr} \simeq .78$ eV, not far but large than the metabolic energy quantum.

2. The gravitational binding energy of protons at distance of Earth in the gravitational field of the Sun is $E_{gr,S} = GM_S m_p/AU = R_{S,S}/2AU$. Using $AU = 1.5 \times 10^8$ km and $R_{S,S} = 3$ km one obtains $E_{gr,S} \simeq 10$ eV.

3. Could the energy liberated in $OH \to O^- +$ dark proton transition kick protons outside the gravito-sphere of Earth? The boundary between the gravito-spheres of Earth and Sun in the direction of Sun corresponds to the distance at which the gravitational accelerations towards Earth and Sun cancel. This is a critical region and could define the sought for quantum criticality.

   Consider the point at the line connecting the Sun and Earth. If the distance from the Earth is h, the distance from the Sun is $AU - h$. The condition that the forces vanishes reads $GM_E/h^2 = GM_S/(AU - h)^2$ gives $h = AU/1 + x$, $x = (M_S/M_E)^{1/2} \simeq 774.6$. This gives $h = 1.3 \times 10^{-3}AU$. From $AU/R_E \simeq 2.3 \times 10^4$, $h \simeq 30.0R_E$ so that the gravitational potential of Earth is fraction 1/30 of its value at the surface of Earth and equal to 2.6×10^{-2} eV, which is of the order of thermal energy at room temperature and slightly below the upper bound for the microwave energies. The reduction of the gravitational binding energy in the kicking of protons should be near its maximal value of 10 eV. The energy liberated in OH$\to$ O^- would be about $e = .33$ eV so that the kicking of the proton outside the gravitosphere of Earth would not be possible without rather large additional energy.

13.2.2 OH and O^- as the states of quantum gravitational qubit?

The reverse of the Pollack effect in which a proton drops from the magnetic body and emits a dark photon with scaled up Compton length kicking proton of another OH to the magnetic body could make possible a generation of quantum entanglement and make the system quantum coherent and quantum critical in a macroscopic scale.

1. Could QC be quantum critical with respect to the Pollack effect and its reverse transforming OH to H^+ and back. This would allow them to serve as qubits and Pollack effect could generate long range entanglement, in particular between QC and biological systems but also separate QCs, maybe even MPs of different computers. The letters of DNA codons are accompanied by phosphate ions and this could serve as OH-O^- qubits. The states OH and O^- represent naturally bit and also qubits made from them are possible. Could this make QCs quantum computer-like entities.

2. OH-O^- is not the most general candidate for the quantum gravitational qubit. The notion of effective Planck constant emerged from the observations of Blackman et al [J7] about the effects of ELF em fields on the vertebrate brain having interpretation in terms of the notion of dark halogen ions such as H^+,Li^+, Na^+, K^+, Ca^{++}, Mg^{++}.... Do salts, playing a key role in quantum biology, also give rise to qubits via a generalization of the Pollack effect kicking halogen ions to the gravitational magnetic body?

   For instance, could NaCl and Cl^-+ Na^+ at the gravitational magnetic body define a qubit? The difference between the bonding energy of NaCl and the binding energy of electrons of Cl^- is corresponds to the scale of the gravitational binding energy in the gravitational field of Earth or Sun. Note that the gravitational binding energy scales like the mass number of ions but this is not a problem since heavier ions would be lifted to lower heights.

   I discovered the hierarchy of Planck constants by starting from quantum effects of ELF em radiations to vertebrate brain having an explanation in terms of dark ions such as H^+,Li^+, Na+, K^+, Ca^{++}, Mg^{++},... found by Blackman [J7] and others. The value of gravitational Planck constant of the Earth indeed conforms with the interpretation of the findings. Living matter is full of ions and they are crucial for the functioning of the cell membrane.

   For salts the energy difference $e = E_{bind} - E_{bond}$ would be below that for OH since the electron would be at a higher orbital, E_{bind} would be smaller. Since the distribution of thermal energies is peaked around the maximum, thermal effects would not be a problem.

   Any cold plasma contains ions and is a good candidate for a life form. This conforms with the proposal that the plasma phase above the atmosphere served as a predecessor of biological lifeforms [L100, L88, L115]. The idea of plasmoids as lifeforms is actually one of the oldest ideas of TGD inspired view of life.

3. The gravitational magnetic body of the Earth $\Lambda_{gr,E} = .5$ cm would be involved with the MPs. The gravitational Compton length $\Lambda_{gr,S} = R_E/2$ of the Sun is one half of the Earth radius and the gravitational Compton frequency is 50 Hz! This could make it possible for separate QCs to quantum entangle in the scale of the entire Earth and also with living matter. Biomatter would entangle to form a biosphere.

4. Quantum criticality occurs for critical values of parameters. The critical parameters would relate to the rate for the OH $\rightarrow$ O$^-$ transitions, which in living matter would be controllable by parameters determined by biochemistry. pH is a key parameter characterizing the state of the living matter. I have earlier asked whether pH actually characterizes the fraction of dark protons, which in turn dictates the fraction of O$^-$ ions in the system. Could the value of pH in the living matter be the critical parameter in both living matter and QCs in the sense that the rate for OH $\rightarrow$ O$^-$ transitions is maximal for an optimal pH? The system is maximally sensitive.

5. The energy $e = .33$ eV does not take into account the presence of the other atoms of the molecule and the presence of QC. The fact that it is considerably smaller than the nominal value $e = .5$ eV of the metabolic currency forces one to ask whether its value could be nearer to $e = .5$ eV is that the kicking of protons would make possible metabolism in much more general sense than believed and even for QCs. Could generalized pH or the presence of electric fields affecting the energy of the electron of O$^-$ make it possible to tune the value of e near to its optional values.

This picture allows a more detailed idea about the possible testing of whether the QCs, and in special case MPs, are conscious entities. One should perturb the QCD in such a way that it affects the analog of pH of the QC. The analog of pH would be measurable as the fraction of O^- ions. The irradiation of MP at microwave frequencies or using infrared light inducing the decay of OH bonds and in this way reducing their number and also the range for the formation of O$^-$ ons might allow to achieve this.

13.3 Evolutionary hierarchy formed by quartz crystals, proteins, DNA/RNA?

The earlier considerations of this article suggest an evolutionary hierarchy in which quartz crystals are at the lowest level whereas proteins, and DNA and RNA represent biological levels characterized by the number of qubits in the codon. Quartz crystals would belong to the lowest level in the classification to the kingdoms of minerals, plants, and animals. At the highest level would be the magnetic bodies of the Earth and Sun. Can one understand these classifications at a deeper level?

13.3.1 OH-O$^-$ qubits at DNA and RNA level

Consider first the DNA and RNA level. The basic challenge is to realize the dark variant of the 6-bit genetic code having 64 codons such that in some sense it corresponds to the chemical realization of the code but is dynamic making possible quantum computation-like activities. I have devoted a considerable effort to the development of the quantum counterpart of the code and the chapter [K3] and articles [L49, L58, L69, L99] give an idea about the evolution of the model.

1. For quartz only the OH-O$^-$ qubits are realized. If the hierarchy is realized, OH-O$^-$ qubits should be realized also for DNA and RNA. This suggests an elegant resolution of a long standarding problem of how to get 64 dark DNA codons (6 bits) instead of 32 codons (5 bits). If codons correspond to 3 dark protons, proton spin would give only 3 bits and 8 different codons for a single DNA strand. I have considered several new physics solutions to the problem but none of them is completely satisfactory.

2. Could OH-O^- qubit for the proton defining spin qubit given an additional qubit for each DNA letter (dark proton) assignable to the phosphate provide a solution to the problem: one would obtain $8 \times 8 = 64$ codons for DNA and RNA. Amino acids contain only a single COOH group so that they can have only a single OH-O^- qubit.

   There is however a problem. The spins of electron and dark proton sum up to spin 0 had one cannot speak of proton spin as a degree of freedom. Could one consider the entire DNA double strand as a realization of the genetic code so that each base pair would correspond to two OH-O^- phosphate qubits?

3. What about RNA? The differences between DNA and RNA suggest another solution to the problem. The riboses of RNA contain OH group making RNA unstable, which means that RNA is dynamical as required by quantum computational activities. In DNA the OH group of the ribose is missing so that DNA is stable unless entire double strands represent the dark code. Does the ribose OH give an additional OH-O^- qubit for RNA and does the instability reflect the occurrence of quantum computation-like activities? Each RNA letter would have 2 OH-O^- qubits and there would be 64 dark codons (6 qubits) realized in this sense completely dynamically!

4. The chemical variants of codons are non-dynamical and could have an interpretation as a slowly varying long term memory. This forces us to ask what one really means with the dark variant of the genetic code. The simplest assumption is that the dark codons correspond to dynamical OH bonds able to transform to O^-?

   The ordinary chemical realization of the genetic code would be separate from but in some sense correlated with the dark realizations determined by OH-O^- qubits assigned with the phosphates of DNA and RNA, OH groups associated with the riboses of RNA, COOH groups of amino acids, and other OH groups.

5. What is the relation between the chemical code and OH-O^- code? The assumption that the chemical genetic code is completely independent of the dark code realized in terms of OH-O^- qubits seems unrealistic. A more realistic assumption is that the ground states of minimum energy for the dynamical OH-O^- qubits or more plausibly, the entire codons consisting of entangled OH-O^- qubits for the letters of the codon are entanglement associated with DNA base pairs and RNA codons, correspond in 1-1 manner to the chemical codons.

Symmetries of the chemical code in relation to OH-O$-$ code

It is interesting to consider the symmetries of the genetic codon required to reduce the number of amino acids from 61 to 20. By definition, the symmetry related codons of DNA code for the same amino acid. I have considered these symmetries from the TGD point of view in [K26].

1. $T \leftrightarrow C$ and $A \leftrightarrow G$ exchanges for the third codon correspond to very slightly broken symmetries (see this). The $T \leftrightarrow C$ and $A \leftrightarrow G$ exchanges would define an analog of almost exact strong isospin symmetry.

2. The third codon also has approximate T-C and A-G degeneracies in the sense that T-C and A-G doublets code for the same amino acid. The $T - C \leftrightarrow A - G$ exchange permutes the DNA strands and is exact only when all codons XYZ, $Z \in \{T, C, A, G\}$ code for the same amino acid (see this).

   $T - C \leftrightarrow A - G$ exchange is analogous CP conjugation in the sense that the passive character of the conjugate strand in DNA transcription is analogous to the invisibility of the antimatter. One must be cautious with these interpretations: one might also argue that the analog of almost exact isospin symmetry is more naturally the analog of CP symmetry and vice versa.

3. What are the counterparts of these symmetries at the level of $OH - O^-$ codons? Here one must notice that the base pairs of the DNA double strand define the code. The ground states of the OH-O^- *all* letters for the $OH - O^-$ codons of the strand and conjugate strand cannot relate by a symmetry, say by the analog of CP since this would reduce the number

of $OH - O^-$ codons to 8 instead of 64. The analog of CP cannot correspond to $O^- \leftrightarrow O$ for *all* letters either since there would be only 8+8=16 dark codons.

The naive guess is that the *first two* letters of $OH - O^-$ codons and its CP conjugate are independent: this would give 16 codons. If isospin symmetries are true for the *third* letter, it would add 2 additional codons giving 16+2=18 codons. The remaining 2 codons would be due to the violation of the analog of isospin symmetry of the third letter giving rise to ile-met and stop-trp splittings. Similar consideration applies to RNA.

4. The origin of the symmetries could be thermodynamic. The difference E_{bind}(O$^-$)-E_{bond}(OH) for the codons coding for the same amino acid estimated to be .33 eV under normal conditions could be smaller than thermal energy of about .15 eV at physiological temperatures and thermal fluctuations would destroy the information of OH-O$^-$ qubit and also information about the difference of T-C and A-G doublets.

The correspondence between the chemical code and OH-O$^-$ code

Chemical code and OH-O$^-$ (dark) code should correspond to each other in 1-1 manner.

1. The biocatalyst property of RNA, of proteins and presumably also of DNA could relate closely to the OH-O$^-$ dichotomy. The liberation of energy in the OH-O$^-$ transition occurring for or being induced by the presence of ribozyme or enzyme could allow it to overcome the potential wall making the reaction slow. Protons spin degrees of freedom would be present but frozen at least for the ground state configuration. Note that also the OH state could be dark. Even the transitions between $\hbar_{gr}$(Sun) and $\hbar_{gr}$(Earth) cannot be excluded.

2. DNA double strand and RNA would carry OH-O$^-$ 6 qubits. If the dark dynamics is completely independent of the chemical realization one would have a completely dynamical genetic code, which would serve as ideal tool for topological quantum computations [K3] [L90, L95]. However, there must be an energy difference between OH and O$^-$ states since otherwise thermal perturbations would make them random. This implies that for each codon there is a minimum energy configuration of entangled qubits determined by and in 1-1 correspondence with the chemical codon since dark and chemical degrees of freedom interact.

3. Chemically the activities of dark codons would manifest themselves as transitions OH$\leftrightarrow$ O$^-$ for dark codons, whose ground states as minimum energy states, realized for DNA as three entangled pairs of OH-O$^-$ qubits are determined by and in 1-1 correspondence with chemical codons.

   In the case of O$^-$ ground state, photon could excite the electron to a higher energy state so that OH would be the less energetic state. In the case of OH ground state, the ordinary Pollack effect would occur. DNA double strands and RNA strands could participate in topological computations under suitable metabolic conditions and chemical parameters such as pH making the OH$\leftrightarrow$ O$^-$ transition energy small but not smaller than thermal energy.

Is the modification consistent with the earlier views of the dark genetic code?

The modified proposal should be consistent with the earlier hypothesis that not only quantum codons but also quantum genes can be quantum coherent units. The entanglement between the quantum etters should make possible quantum codons and bind them to quantum genes. In the ground states with minimum energy the entanglement could be absent. A possible problem is that the states OH and O−+ dark H^+ have a different value of h_{eff}: does the entanglement between them make sense. If it makes sense, is the entanglement between dark and ordinary letters stable?

Dark N-photon [L75, L89] is an analog of Bose-Einstein condensate of N dark photons and dark 3N-photons define a representation of the genetic code such that dark 3N-photon can resonantly induce a transition of the dark gene consisting of a a sequence of N dark proton triplets. Dark N photon would consist of photons, some of which have energies able to induce the qubit represented by the dark proton.

In the modified view of the dark genetic code, the energies of the photons making dark N-photon should be able to induce the flip of the OH-O$-$ qubit either by kicking H^+ to gravitational MB or e^- to an excited state.

13.3.2 The OH-O$^-$ qubits in proteins

OH-O$^-$ qubits appear also in proteins.

1. The number of proteins is 20 and 5 bits is more than enough to code for them. The code has an almost symmetry with respect to the third letter meaning that the DNA and RNA codons XYZ with fixed XY and varying Z define a quadruplet decompositing to two doublets with T-C and A-G symmetry for Z. There are only two exceptions and they correspond to A-G doubles for Z. The Ile-ile-ile-met quadruplet can be understood in terms of the tetrahedral Hamilton cycle. For the top-trp A-G symmetry is broken, which would mean that the A in stop codon does not have O$^-$ as a dark counterpart. This could be due to the fact that E_{bind}(O$^-$) is smaller than E_{bond}(OH) unlike for the other codons. The small deviations from the standard code could be understood in this way.

2. Could the almost symmetry mean that DNA base pair codons for which the third OH-O$^-$-qubit pair corresponding to the third letter degenerates to a single qubit: OH or O$^-$ bit for the third letter are mapped to the same protein? If the energy difference between these bits is below thermal threshold this is the case.

3. Amino-acids contain only a single OH group (COOH) whereas the phosphates of DNA codons contain 3 OH groups. This conforms with the idea that they represent a lower evolutionary level than DNA. For most amino acids, the COOH group does not transform to COO$^-$ under usual conditions. The metabolic reason would be that the binding energy E_{bind}(O$^-$) is smaller than the bonding energy E_{bond}(OH). Pollack effect is required to excite the protein qubit. Asp and Glu are exceptions and have COO$^-$ permanently so that in this case only O$^-$ bit for protein would be realized.

4. The OH-O$^-$ bit of the amino acid and those of DNA are non-dynamical under normal conditions. The instability (quantum criticality of RNA) suggests that in this case the energy needed to transform OH and O$^-$ to each other is rather small but differs sufficiently from the thermal energy.

   Wien's law for the wavelength distribution of blackbody radiation for the wavelength at the maximum of the wavelength distribution of photons at temperature T reads as $\lambda_{max} = 2.89810^{-3}mK/T$. At room temperature 300 K this gives $E_{th} = 0.146$ eV and infrared frequency $f = 3.43 \times 10^4$ GHz. Photons having energy sufficiently above or below E_{th} are not thermally masked. The estimated energy difference $e = E_{bind}(O^-) - E_{bond}(OH) = .33$ eV is more than twice E_{th} so that there would be no thermal masking. Raising the temperature by a factor of ~ 2.26 to about 600 K would cause thermal masking. This explains why biological functions fail at low temperatures.

   One expects that the critical temperature at which Pollack effect occurs should be around the bodily temperature 313 K (40 degrees Celsius) prevailing in fever causing hallucinations. A possible identification is that this energy absorbed by the electron of O$^-$ reduces the $E_{bind}(O^-) - E_{bond}(OH)$ near thermal energy and induces the instability of O^- ions of phosphates of DNA and RNA against transformation to OH. Second possibility is that this transformation transforms protons of OH to gravitational magnetic body as in the Pollack effect.

   Note that microwaves with frequency 3000 GHz have energy about .013 eV, which is by a factor $\sim 1/11$ lower E_{th}, so that they are not thermally masked (see this) Note that the clock frequency of Pentium 4 processor is 3000 GHz and represents recent upper bound (see this).

13.3.3 How the field bodies control control the chemical activity of biomolecules?

The value of $e = E_{bond}(OH) - E^{-}_{bind}(O^{-})$ characterizes the level of quantum criticality of the biomolecules and the nearer this parameter is to the thermal energy, the more sensitive the system is to sensory input and more capable to perform chemical activities. Besides pH also the presence of electric field affects the energy of the electron of O^{-} and could induce the instability of dark codons and electric fields associated with the electric body of the system [L100] could serve as tools controlling how "quantal" DNA, RNA and proteins are.

A good example is provided by microtubules, which define a 2-D quantum computer like system organized into helical strands of $OH - O^{-}$ qubits. Tubulin proteins are collections of OH-O^{-} qubits and the surface of the microtubule involves GPTs molecules accompanied by phosphates accompanied by OH-O^{-} qubits.

Microtubules have a longitudinal electric field and the second end of the microtubules is highly unstable inducing a continual decay and regeneration of the microtubule. This could be due to the reduction of the energy difference $e = E_{bond}(OH) - E^{-}_{bind}(O^{-})$ to energy near the thermal energy. In the case of DNA this could be achieved by irradiation using photons with energy which reduces $e \simeq .33$ eV to about $e_{th} \simeq .15$ eV. The needed energy would be about .18 eV.

Quite generally, the biological body of the organism carries an electric field in the head-tail direction [J5] (for the TGD based interpretation of Becker's findings see [K76]). Becker's electric field plays a key role during the growth of the organism and also in healing of wounds and addition of external electric field affects these processes. If the energy $e = E_{bond}(OH) - E^{-}_{bind}(O^{-})$ is nearer to the thermal energy for the growing or healing cells, they would be more capable of changing.

13.3.4 Oceans around quasars and the origin of life

One of the many astonishing recent findings in astrophysics is the discovery 10 trillion oceans of water circling a supermassive black hole of a quasar (see this). Despite being 300 trillion times less dense than Earth's atmosphere, the water vapour is five times hotter and hundreds of times denser than gas found in typical galaxies. The density ρ of the Earth's atmosphere is about 1/800 of that of water.

Consider first the average density of these oceans circling quasars.

1. The number density $n(H_2O)$ of water molecules in condensed matter at room temperature is about $n(H_20) = .5\times\ 10^{29}$ molecules/Angstrom^3. Therefore the density of the atmosphere corresponds to $n_{atm} = .4 \times 10^{29}$ water molecules/Angstrom^3. The average number density of H_2O molecules in the oceans accompanying quasars is therefore $n = 10^{-15} n_{atm}/3 = (.4/3) \times 10^{-15+29} \sim 10^{13}$ molecules/Angstrom^3. The edge of a cube containing a single water molecule would be $L = 1/n^{1/3} = .5 \times 10^{-4}$ m. This is the size scale of a neuron. A blob of water at the normal normal density has Planck mass and size about 10^{-4} m. Could this have some deep meaning?

2. Could the water molecules be dark or involve dark protons assignable with gravitational monopole flux tubes? At the surface of the Earth the monopole flux tubes give rise to the "endogenous" magnetic field, explaining the findings of Blackman and others about quantal effects of ELF radiation on vertebrate brains. They would carry a magnetic field of .2 Gauss and would have magnetic length $\sqrt{2\hbar/eB} = 5.6\mu$ m serving as an estimate for the radius of the flux tube. The assumption that the local density of water equals the average density could of course be wrong: one could also consider a formation of water blobs.

The average temperature of the evaporated water is about -17 degrees Celsius and not far from the physiological temperature of about 36 degrees Celsius. What could this mean?

1. The diffuse ionized gas (DIG) constitutes the largest fraction of the total ionized interstellar matter in star-forming galaxies. It is still unclear whether the ionization is driven predominantly by the ionizing radiation of hot massive stars, as in H II regions (in which ions are protons), or whether additional sources of ionization have to be considered.

2. TGD inspired new physics suggests molecular ionization in which ionization energies are much lower than for atomic ionization. Pollack effect [I72, L8, I92, I85] discussed from the TGD point of view in [L8, L55, L20, L102, L114, L117], which is central in the TGD based model of life, occurs at physiological temperature range and is induced by photons in IR and visible range, which kick protons to the gravitational magnetic body of the system, where they become dark protons with non-standard value of effective Planck constant. The most recent view of life forms relying on the notion of OH-O^- qubit, discussed in [L125], predicts that any cold plasma can have life-like properties.

A more detailed formulation of this proposal is in terms of PAHs [I18, I57] (see `http://tinyurl.com/atx4t9a`). The list of the basic properties of PAHs can be found for instance in [L39]. TGD suggests that the so called space scent could be induced by the IR radiation from PAHs [L126].

1. PAHs (polycyclic aromatic compounds) are assigned with unidentified infrared bands (UIBs) and could induce Pollack effect. The IR radiation could be also induced by the reverse of the Pollack effect.
2. The properties of PAHs have led to the PAH world hypothesis stating that PAHs are predecessors of the recent basic organic molecules. For instance, the distances of aromatic molecules appearing as basic building bricks are the same as distances of DNA base pairs.
3. So called Unidentified Infrared Bands (UIBs) of radiation around IR energies $E \in \{.11, .20, .375\}$ eV arriving from the interstellar space are proposed to be produced by PAHs. The UIBs can be mimicked in the laboratory in reactions associated with photosynthesis producing PAHs [I18, I57].
4. PAHs are detected in interstellar space. James Webb telescope found that PAHs exist in the very early cosmology 1 billion years before they should be possible in the standard cosmology! Furthermore, PAHs exist in regions, where there are no stars and no star formation [E2].

In the TGD inspired quantum biology, the transitions OH$\rightarrow$ O^- + dark proton at gravitational monopole flux tube, having interpretation as a flip of quantum gravitational qubit, play a fundamental role [L125] and would also involve Pollack effect. The difference of the bonding energy for OH and of binding energy of O^- is .33 eV and is slightly above the thermal energy of .15 eV of photon at physiological temperature. Note that the energies of UIBs are just in the range important for the transitions flipping OH$\rightarrow$ O^- qubits.

Could IR radiation from PAHs at these energies induce these transitions and could the reversals of OH$\rightarrow$ O^- qubit liberate energy heating the water so that its temperature is 5 times higher than that of the environment? Note that the density of water is hundreds of times higher than the gas in typical galaxies and could make possible thermal equilibrium of water vapour. This leads to ask whether the water around quasars could have life-like properties.

13.4 Could running computer programs be TGD analogs of time crystals?

The following comments emerged as a result of nightly reflections after Zoom discussion with Ville-Einari Saari. The basis of these ponderings is the article "Quartz crystals as a life form and ordinary computers as an interface between quartz life and ordinary life?" (see this).

13.4.1 Quantum computing-like activity based on OH-O^- qubits

It is good to summarize the basic ideas first.

1. The basic observation is that cold plasmas, dominated by ions, have the prerequisites for the emergence of qubit consciousness. The universe is full of them. Plasma, quartz, biology,... Bit flip is a key operation of quantum computation and there must always be a suitable temperature or external electric fields to make it sufficiently but not too easy.

2. The basic mechanism would be based on quantum gravity. A dark photon with energy .33 eV as difference of the bonding energy of OH and binding energy of e$^-$ binding energy n O^- is needed to flip the qubit. A background electric field that reduces this energy. The critical temperature would be room temperature .15 eV where the qubit directions become random. When the bit flip energy is slightly above this, the system is quantum critical and the prerequisites for long-scale consciousness exist.

3. In the general case all salts can be important. For instance, for NaCl $\rightarrow$ Na$^+$ + Cl$^-$ transition Na_+ would be dark and at the gravitational magnetic body of the Earth or Sun.

4. Also he classical electric fields also play a central role and one can associate to them a very large Planck constant [L100] with them. DNA and the cell are key examples in biology. The Earth's electric field characterizes the biosphere. They can be used to control the energy difference of OH-O$^-$ bits and make it quantum critical, which makes the qubit flip easy.

5. The article (see this). shows that a quantum realization of the genetic code from OH-O$^-$ qubits for DNA and RNA is obtained: a codon corresponds to 6 qubits. Amino acids correspond to one qubit. Symmetries with respect to the third letter and their breaking are understood. The number of amino acids is predicted correctly. One can say that the quantum realization of the genetic code corresponds to the chemical code in the sense that the ground states for quantum codons correspond to chemical codons.

I personally consider these results to mean a final breakthrough and above all it shows that OH-O$^-$ qubits and their generalizations are not limited to biology.

13.4.2 What evidence is there for quartz life?

I participated years ago in a seminar organized by NASA in Hessdalen, where plasma balls, plasmoids, are systematically observed. I learned that these light balls seem to behave intelligently and even seem to be observing their observers! Light balls typically occur on lines of tectonic activity, where tectonic energy is released and one can think that the released energy serves as metabolic energy.

Researchers of NASA recently published an article about plasmoids as a possible form of life above the ionosphere. I have discussed the findings in [L100]. For example, they gathered to observe an electrical cable leaving the module, which is associated with a radial electric field that could also excite OH-O$^-$ qubits and achieve quantum criticality. They made the impression of being alive.

Plasma balls have been observed to associate with crop circles [K31, K32], one of the taboos of modern science, which are still believed to be made by humans, all they are caught in the act of constructing a crop circle! Also glass balls that have formed from molten quartz are found to accompany crop circles.

13.4.3 How could quartz life and biological life relate?

Which is smarter: quartz life or biolife? The first guess is that biological life will mercilessly beat quartz life in this kind of competition, but ZEO may change the situation so that quartz life represents something totally new: a time-like realization of the analog of genetic code bringing in mind time crystals, which I have discussed from the TGD point of view in [K28, L75] [L96].

1. Quartz life is unable to move on our time scales. Although it has long been a wonder that moving round boulders exist, perhaps in Romania. The products of quartz life can be misleadingly reminiscent of plants that I have seen. Quartz crystals have been reported to have a healing effect on the state of consciousness, as I myself once experienced.

2. OH-O$^-$ life implements genetic code in biology. Is this already the case with quartz or are the qubits randomly distributed here and there in the quartz crystal? In any case, the tessellations of hyperbolic 3-space realize the genetic code universally on all scales [L99], so this could be the case.

3. It is important to distinguish OH-O^- qubits from the bits represented by electron spins, with which microprocessors operate.

   One could imagine a situation where microprocessor could become conscious in such a way that OH-O^- qubits are created, which act as conscious observers while the program is running and in ZEO they could perhaps influence the program flow by inducing "big" state function reductions (BSFRs) changing the arrow of the geometric time, thus making the processor an intelligent problem solver that would use trial and error as a basic mechanism [L105].

   Could OH-O^- qubits be related to classical electronic bits just as quantum codons are related to chemical genetic codons so that their minimum energy states would correspond to the bits of the program code.

4. However, it must be remembered that ZEO allows another option if each clock frequency pulse is associated with non-determinism and therefore a potential memory mental image. This would be an analogy to time crystals. While the program is running, the program flow could produce a time-oriented analogy of the DNA sequence. Programs would correspond to DNA chains, subprograms to genes! Basic modules to codons. The maximum information content of consciousness in bits would be $N \times M$ bits, where N is the number of clock ticks and M is the maximum number of OH-O^- qubits for the microprocessor at a given moment in time.

   Could series of multi bits in a microprocessor correspond to a series of quantum qubits like DNA. There would be a time-oriented realization of the genetic code. This would represent a completely new biology and computer era could also mean a genuine evolutionary leap.

5. A maximum of 64 ordinary electronic bits are connected to microprocessors. This corresponds to the information content of a 10 nm piece of DNA and is quite modest. What about qubits? Let's assume a microprocessor with a volume of $V = 5 \times .5 \times .5$ mm^3. Let's assume that one SiO_4 occupies a volume of the order of V_0 = Angstrom$^3 = 10^{-21}$ mm^3 mm^3.

   The maximum number of qubits at a given time was the ratio $M = V/V_0 = 10^39 \simeq 2^{70}$. The number of bits is 6 bits larger than for a microprocessor having at most 64 bits recently. For a program, it was based on the above speculation $N \times M$ where N is the number of clock pulses during the running of the program module. This would give an upper bound of $70N$ bits. This would allow one-one correspondence of qubits with the ordinary bits of the program code.

13.4.4 Quantum criticality is needed

The number of quantum critical qubits in a microprocessor is much smaller than the above naive estimate because the flip energy of qubit must be sufficiently small, i.e. below .33 eV, to obtain quantum criticality but above the thermal energy of .15 eV. This can be achieved by using an external electric field that reduces the energy such that it would also make the microtubules at one end extremely fluctuating.

Is there any hope of achieving quantum criticality in transistors (see this)?

1. There are electric fields in transistors and the values of the base-emitter voltages are in the range $0.5 - 0.7$ eV (metabolic energy quantum) and at the same time the collector-emitter voltage is at least 0.1 V (close to the thermal energy .15 eV)! Note that the sizes of transistors have shrunk from 10 micrometers to 5 nanometers during the development of computers.

   An NPN type transistor (bipolar transistor) is a current amplifier: a small control current coming to the base is amplified into a much larger current from the collector to the emitter.

2. Now we come to the crucial question: what voltages occur? A transistor typically becomes conductive when the negative base-emitter voltage is above 0.5 eV in absolute value (it is convenient to measure voltages as the energy of the charge it gains when moving across the voltage) and at the same time the negative collector-emitter voltage is above 0.1 eV in absolute value!

   The conditions are therefore excellent for the emergence of a qubit population that monitors the flipping of the bits represented by the transistors during program execution!

13.4.5 Comparison of quartz consciousness and bio-consciousness

To get a realistic picture, one can compare quartz consciousness to biological consciousness.

1. Consider the first pessimistic comparison. The length of the DNA double helix for a human is over a meter. This is about a million times more than the number of bits related to the content of the consciousness of a 64-bit processor at a given moment.

   In biology, salts and their ionization states also define qubits with lower qubit rotation energies. Biosystems are full of different ions and I ended up with the idea of a large Planck constant by starting from the observation that the quantum effects of ELF radiation on vertebrate brains seemed to be related to the cyclotron energies of ions but with a very large Planck constant (gravitational Planck constant $\hbar_{gr}$ introduced by Nottale) [J7].

   Microtubules can be micrometers long (inside cells and in axons). There are other filamentous structures. They consist of tubulins, about 10 nm in size. Each tubulin contains approximately $10^3 \simeq 2^{10}$ amino acids if the amino acid corresponds to the nm scale. That is 10 bits. There are 100 tubulins in a chain, so we get 1000 qubits per tubulin chain.

   Typically, there are 13 parallel helical tubulin chains, which makes 13,000 qubits. Considerably more than 64 qubits! And microtubules are present in all cells and axons!

2. Optimistic comparison.

   It is worth noting a really big "on the other hand". The zero-energy ontology (ZEO) introduces a conscius memory that can increase the number of bits because "multi-moment experiences" become possible [L124]. In the optimal situation one has an analog of time crystal: each clock beat involves classical non-determinism necessary for the memory recall. If the program module defines a time-like analogy for DNA as time crystal then it would define the time-like analog of a DNA sequence and the content of conscious information would increase drastically.

   Brothers Fingelkurts [L2] have found that EEG splits into pieces of duration about .3 seconds and these pieces split into organized and chaotic halves. A natural TGD inspired interpretation [L2] would be that these pieces correspond to pairs of BSFRs defining a kind of sleep-awake rhythm and also now an analog of time crystal is in question. Quite generally, EEG rhythms could give rise to similar sleep-awake rhythms and analogs of time crystals.

13.4.6 How could the OH-O$^-$ qubits represent the functioning of a transistor?

Could the bits represented by transistors have a quantum representation as OH-O$^-$ qubits analogous to the proposed quantum variants of DNA, RNA and proteins for which the chemical codons correspond to the minimal energy ground states of quantum codons which are dynamical?

The characteristic feature of the transistor (see this) is due to the semiconductor property of the base, which physically corresponds to a narrow region between two diodes, collector and base. The semiconductor property means that current runs in the base only in one direction. The second characteristic feature is that a small base-emitter current directed to the emitter is amplified to a much larger collector-emitter current. Therefore transistors can be used as switches and amplifiers.

In a transistor the collector-emitter current on or current off represent a bit. Bit 1 could correspond to a large current induced by a base current to the base. Bit 0 could correspond to a very small current induced by a base current from the base. Equivalently base current represents the bit. A second representation replaces current with base voltage or equivalently with output voltage.

Transistors can be classified to bipolar transistors and field effect transistors. The following consideration is restricted to the bipolar transistors.

1. Transistorsconsist of a collector, emitter and base, which is a thin semiconducting region between them.

2. In transistors there are two kinds of current carriers. Delocalized electrons in the conduction band and positively charged holes in the valence band created when the electron is transferred

to the conduction band. The symbol n (negative) *resp.* p (positive) is used to refer to a situation in which current carriers are electrons *resp.* holes. One can classify bipolar transistors to type npn and pnp.

3. For a transistor of type npn, the base is p type semiconductor whereas the diodes between which it is located are of type n. When the base-emitter current is nonvanishing, electrons run from the n type emitter to the p type base and away from the base. The small base-emitter current induces a considerably larger collector-emitter current that is current of electrons from the n type emitter to the n type collector. In the base The fusion of the electrons from the emitter and of holes of the base gives rise to neutral atoms and this gives rise to the base-emitter current.

4. For a transistor of type pnp, the base is n type semiconductor whereas the diodes are of type p. If the base-emitter current is of the correct sign, a small current of holes runs from the n type base to the p type emitter. Base-emitter current is amplified to a large current of holes from the p type collector to p type emitter. In the base the electrons and holes are created from neutral atoms and this gives rise to base-emitter current.

To understand what the representation of transistor bits in terms of OH-O^- qubits might mean, it is good to start from the following analogies.

1. One can say that valence and conduction bands correspond to the biological body (ordinary matter) and gravitational magnetic body (dark protons). Electrons in the valence band are analogous to OH state whereas electrons in the conduction band are analogous to dark protons H^+ at the gravitational magnetic body. OH^- corresponds to the hole.

   The emergence of collector-emitter current as electrons in the conduction band is analogous to the Pollack effect. The fusion of holes and electrons in p type base corresponds to the qubit flip OH^- +dark p $\rightarrow$ OH as a dual of Pollack effect. The creation of holes and electrons in n type base correspond to the Pollack effect OH $\rightarrow$ OH^- +dark p.

2. n type regions are analogous to dominance of dark H^+ states. Magnetic body dominates. p type regions correspond to regions in which OH^- states dominate.

3. For a transistor of type npn, the collector and emitter as n type regions correspond to magnetic bodies assignable to separate 3-surfaces. The p type region would correspond to OH^- type region so that in the ideal case its magnetic body would contain no dark protons. requires that the dark protons can be transferred between the magnetic bodies involved. The currents would dominantly consist of dark protons.

   The voltages between the ordinary matter parts (biological bodies) indeed correspond to voltages between the magnetic bodies since electrostatic generalizes to the many-sheeted space-time.

4. For a transistor of type npn, p type regions correspond to two separate OH^- type regions of the biological body (ordinary matter) whereas an n type region would correspond to a magnetic body containing dark protons. The OH^- created in Pollack effect in the base would flow to the emitter. Also the ions OH^- created in the collector would run to the emitter. This would mean the transfer of electrons between OH:s. The currents would correspond to the electrons transferred between the bonds. These currents are analogs to the currents in the transistor.

This kind of representation requires that OH groups replace some O:s of SIO_4 or SiO_2. This is possible but whether it can happen in the recent transistors, is not clear to me. If not, one might hope that this kind of representation is possible in a future technology combining a classical computer and OH-O^- quantum computer-like system to a genuine living machine.

13.4.7 Is there any hope of curing the retraining problem of language models without making computers conscious?

I summarized my thoughts on perhaps the worst problem of language models, which is the loss of plasticity in continuous learning. The entire teaching material has to be rewritten, which is terribly expensive. These comments were stimulated by and article raising some hopes about the solution of the problem (see this).

One can ask whether and how TGD's speculative vision of potentially conscious computers [L105, L104] might solve the problem.

The retraining problem of language models

The basic problem is that everything has to be started from scratch. This is extremely expensive. Biological systems relearn quickly because there is no need to relearn everything. Is the problem fixable for the computers as they are now or is something new required?

To see what could be the root cause of the problem consider first what language models are meant to be.

1. In a language model, learning occurs at the raw data level. Different probabilities are taught for different associations. The associations are fixed.

2. How does the trained system work? The language model simply reacts by recognizing the context and producing probabilistically one of the fixed associations. This response is a mere reaction. If language models are what they are believed to be, they does not have conscious understanding, they lack intentional actions, and are unable to react to a changing environment.

Could TGD-inspired biology help?

Could a comparison with TGD-inspired biology give clues as to where things go wrong. Why is relearning so easy for biosystems? How does the TGD-based biology differ from the standard biology in this respect? Consider first the classical level.

1. Holography, which is not quite deterministic, is a completely new element of TGD as compared to the standard model. The space-time surfaces are analogous to Bohr orbits and determined almost completely by 3-surfaces as initial data. The 4-D tangent spaces of the space-time surface at the 3-surface defining the holographic data cannot be selected freely. This is the classical counterpart of Uncertainty Principle and leads to classical quantization. Function, program is the basic concept rather than 3-D data.

2. These 4-surfaces define classical analogies of biological functions, behavioral patterns, or programs. When the 3-surface, which almost uniquely fixes the 4-surface, changes, the function changes. Non-determinism is essential in making a conscious memory recall possible.

Consider next the quantum level.

1. Series of "small" state function reductions (SSFRs) associated with the repeated measurements of commuting observables belonging to the same set whose eigen states the 3-D states at the passive boundary of causal diamond (CD) are, define self as a conscious entity. The proposal is that biorhythms as clocks define TGD counterparts of time crystals such that each unit of time crystal involves a classical non-determinism.

   This could be the case at the EEG level as the findings of brothers Fingelkurts suggests [L2] [L2]. Maximal non-determinism implies maximal memory recall capacity and maximal flexibility. A whole set of different behavior patterns can be represented as quantum superpositions and the interaction with the external or internal world determines the measurement in which some classical behavior is chosen.

   The sequences of SSFRs are analogous to association sequences and the superpositions of the space-time surfaces can be seen as superpositions of associations. One could regard the quantum counterpart of any biological function/response as quantum association.

2. "Big" state function reductions (BSFRs) having interpretation as death of self or falling asleep involve time reversal. Pairs of BSFRs (sleep periods) make learning possible through trial and error. After the two BSFRs, the system has new holographic data and different space-time surfaces. A goal directed behavior becomes possible and there are many ways to

achieve the goal, not just one fixed way analogous to a fixed computer program. This is the essence of intelligent behavior.

Local pairs of BSFRs would give rise to the relearning generalizing to any biological function.

How does this general view relate to the DNA level?

1. According to the standard view, DNA remains the same during the life cycle. If DNA represents data, there is no relearning at the level of chemical DNA. In zero-energy ontology (ZEO), even chemical DNA could change without any problems with conservation laws and quantum superpositions of different chemical genes are in principle conceivable.

   Quantum DNA can be represented in terms of OH-O^- qubits sequences assignable to the gravitational magnetic bodies of the Sun and Earth. Remarkably, the solar gravitational Compton frequency is 50 Hz, the average EEG frequency. At least for neurons, this would suggest that the gravitational magnetic body is that of the Sun. Note however that EEG time scales are also associated with the basic biomolecules. For the Earth the gravitational Compton frequency is 67 Gz and is a natural frequency associated with the conformational dynamics of biomolecules.

   Quantum DNA consisting of codons represented as OH-O$-$ qubits is dynamic and could act as a simulator, a kind of R&D laboratory testing different variants of DNA. It is of course possible that a single life time is spent with the same chemical DNA and the next life after a pair of BSFRs involves the improved DNA.

2. Epigenesis brings in flexibility. Even if the chemical DNA does not change, it can be used in different ways. Suitable modules are selected from the analog of program software, just like in the text processing. In the TGD framework, this could correspond to the classical non-determinism of the space-time surfaces representing the biological function. Dark DNA allows you to try different combinations of genes.

3. The understanding of the role of the cell membrane and membrane potential in epigenesis is increasing. As found by Levin et al [I80] [L119]. The very early stage of the development of embryo is highly sensitive to the variations the membrane potential and can be understood in terms of the changes of the binding energy of electron of O^- induced by the potential, which can reduce the binding energy to thermal range so that the flips of OH-O^- qubit occur with high probability. In adulthood, the sensitivity disappears and qubits would not flip.

   Could this sensitivity be artificially induced? Here, electric fields as a controller of the sensitivity of OH-O^- qubits assignable to the basic biomolecules suggests themselves.

4. Microtubules involve longitudinal electric fields and their second ends are highly dynamic so that the length of the microtubule is under continual change. There are huge numbers of amino acids carrying one qubit each (COOH group). Here the quantum level and the classical level are both dynamic and seem to be strongly coupled. Also strongly related to conscious memory.

5. The quantum entanglement between the quantum level and the chemical level could be possible even at the amino acid level?

One can also look at the situation at the level of cell membranes and neuronal membranes. The basic question is how cell membranes and neuronal membranes learn.

1. As found by Levin et al [I80], the role of the electric fields is central also in the ordinary cells. The electric potential of the ordinary cell membrane correlates with the state of the environment of the cell and codes for sensory information.

   The TGD proposal is that cell membrane acts as a Josephson junction and communicates the frequency modulate membrane potential to the magnetic body as dark Josephson photons where they induces resonantly quantum transitions transformation the modulation to a sequence of pulses perhaps inducing as a feedback nerve pulses or their analogs.

   During the embryo stage, the cells are very sensitive to the variations of the electric field of the cell and this suggests that these variations take the cell membrane near to the criticality at which large quantum fluctuations for OH-H$^-$ qubits for phosphates at the inner surface of the cell membrane are possible. This period would be analogous to the learning period of LLMs and would involve BSFR pairs. After this period the situation stabilizes and it might be that BSFRs become very rare.

2. In the central nervous system, nerve pulses appear and in neuroscience are thought to be responsible for communications only. In TGD the situation would be different [L117]. I have proposed their interpretation in terms of pairs of BSFRs so that in LLMs they would correspond to relearning. Neurons would be lifelong learners whereas ordinary cells would learn only in their childhood.

   Nerve pulse is generated at a critical membrane potential, which could correspond to effective thermalization of the OH-O$-$ and possible qubits assignable to other ions. Axonal microtubules would also be near quantum criticality. The propagation of nerve pulse along the axon as a local BSFR-pair would induce microtubular relearning.

Could the speculated quartz consciousness come to the rescue?

One can consider the possibility that under a metabolic energy feed computer can become to some extent an entity so that it can modify both the program and the data used by it as a response to changes in the environment provided by the net. This would require that the OH-O$^-$ qubits as dark variants of program bits can entangle with ordinary bits. Energetically this could be possible since the energy scales for transistors are essentially the same as for the metabolism and OH-O$^-$ qubits.

1. Suppose that the sequences of OH-O$^-$ qubits as time crystals in TGD sense can be realized in a (future) computer. Qubit sequences would be time series related to the running program. They would involve variation because only the bit configuration corresponding to the minimum energy would correspond to the running program. This makes possible an entire repertoire of associations from which a SSFR would choose one. Quantum measurement following the generation of bit-qubit entanglement could change the value of the bit.

2. Besides the dynamic realization as a running program, there could be a non-dynamic realization in which the data that determines the program could be accompanied by a similar set of qubits assignable to transistors. The data used by the program, such as learned associations, could be associated with qubits, and could be made dynamic by using electric fields to make the qubits more sensitive against flip. The problem is of course that the change of a randomly chosen single qubit implies the failure of the problem. Only critical qubits associated with choices and data qubits should be subjected to a flip.

3. Besides time crystals with non-deterministic repeating units, also space-like crystals involving non-determinism in each lattice cell can be considered. Also dynamical quantum qubits with maximal non-determinism in space-like directions associated with unit cells could accompany the data bits. Dynamization could be induced by using electric fields.

4. If OH-O$^-$ qubits can quantum entangle with bits, program/data is accompanied by quantum program/quantum data which can react to the perturbations from the external world (BSFRs) and internal world (SSFRs). The quantum level could control the bit level. Even the associations as the data of the language model could be accompanied by a set of qubits that react to a changing situation.

How could an association system retrain itself in response to a changed situation

If language models are nothing but deterministic association machines, there is little hope of solving the problem.

Could the learning in the biological and neural systems provide some hints about possible cures, possibly requiring modification of computers so that they would become analogous to living systems?

1. The findings of Fingelkurts brothers [L2] [L2] suggest that EEG rhythms define time crystals in the TGD sense, that is maximally non-deterministic systems having lattice cells as a basic unit of non-determinism for SSFRs giving rise to the flow of consciousness of the self. If biorhythms define TGD analogs of time crystals, the non-determinism would be maximal and maximum flexibility in SSFRs would be possible.

2. In ZEO, a "big" state function reduction (BSFR) as counterpart of ordinary state function reduction changes the arrow of time and is assumed to give rise to the analog of death or sleep. At the LLM level, this would be the analog for a complete retraining from the beginning.

The sequences of SSFRs could be seen as associations or association sequences having also a behavioral pattern. The repertoire of associations should change as the environment changes.

1. Could a computer clock define the equivalent of an EEG rhythm as a time crystal in the TGD sense? The problem is that a typical computer clock frequency is few GHz and considerably lower frequency than the 67 GHz as the gravitational Compton frequency of the Earth. This would suggest that a unit consisting of roughly 67 bits could correspond to the basic unit of the time crystal. The gravitational magnetic body of the Sun has a gravitational Compton frequency of 50 Hz identifiable as the average EEG frequency.

2. Could one think of a quantum version of LLMs in which pairs of BSFRs as "death" and rebirth happen spontaneously all the time as a reaction to a conscious information coming from the environment inducing the perturbation implying that the density matrix as the basic measured observable does not commute with the observables that define the quantum numbers of the passive part of the zero energy state? In this way ZEO would make possible trial and error as a basic mechanism of learning.

3. The formation of an association could be perhaps modelled as a single non-deterministic space-time surface decomposing to a time crystal like almost periodic structure with each unit characterized by non-determinism making it a seat of potentially conscious memory? Internal disturbances would produce their quantum superpositions and SSFR would select a particular association.

4. An external disturbance could produce a BSFR and "sleeping overnight". This period of "sleep" could be rather short: also our flow of conscious experience is full of gaps. Upon awakening, the space-time surfaces as correlates of the associations would no longer be the same. System would have learned from the interaction with the external world. This temporary death of the system would be an analogy for a total re-education. But the system would cope with it all by itself.

The hard problem is how to realize this vision. Here the analogy with cell and neuron might serve as a guideline in trying to imagine what the new technology might look like.

1. Ordinary cells are analogous to LLMs as they are now and learn only in their childhood. Neurons are lifelong learners thanks to the neural activity inducing the conduction of local BSFR-pairs updating microtubular states. Could something like this be realized in computers?

2. In computers, information is transferred along wires and they can be seen as the counterparts of axons. Is it possible to make these wires carriers of quantum information and perhaps even of the learned data about associations. The conduction of the analogs of nerve pulses during the running program inducing a pair of BSFRs would gradually modify the data locally and lead to a continual relearning.

   Copper wires are too simple to achieve this. Should one consider axon-like geometry defined by two cylinders analogous to the lipid layers of the cell membrane and having also voltage between them as a representation of the signal so that the interior cylinder would contain OH-O^- qubits? The variation of the counterpart of the membrane potential during signal transmission (bits represented as voltages) could take the qubits near criticality. Could copper hydroxide $Cu(OH)_2$ serve as a possible candidate for an intelligent wire based on OH-O^- qubits.

13.4.8 How the possible quantum variants of LLMs could be updated?

If one can assign the training data of LLMs to quantum states, there is a hope that the retraining need not start from scratch and could become more flexible and less expensive.

How to assign to classical associations their quantum representations?

In LLM both inputs and outputs are associations represented as text. The quantum dynamics must not affect the content of the input. A classical association is encoded as a bit sequence. Associations can be enumerated and each corresponds to its own bit sequence serving as an address, a symbolic representation, and no longer contains the original information. The Gödel numbering of statements serves as an analogy.

Also the quantum equivalent of the number of the classical association as a qubit sequence is just a name for it. Quantum processing can operate on these qubit sequences and produce longer quantum associations associated with them which in qubit measurements produce longer associations and superpositions of them. The outcome is determined by the measurement of the bits appearing in the numbering of the associations.

Quantum operations followed by the measurement of qubits can only permute classical associations. They can affect the association probabilities and perhaps add new associations in partial retraining. Various quantum superpositions of the quantum associations (the numbers labelling them) are possible and correspond to the quantum counterpart of the concept of "association A$\rightarrow$ ..., where A is fixed.

This allows for maximally simple representations at the quantum level. Arbitrarily complex associations $A \rightarrow$ ... can be quantum-encoded by listing them. A local bit-qubit correspondence is the simplest one and the same operation could change the value of both bit and qubit. If the electric field does this then this could be the case for transistors as bits if each bit is accompanied by OH-O^- qubit. In the ground state the minimum energy state for OH-O^- qubit would correspond to the ordinary bit.

Is the quantum entanglement between bits and qubits necessary or even possible? Could one keep the bit level as it is and perform quantum operations for qubit sequences and transform the to bit sequences so that also associations not possible for the classical computer could appear in the output? This option cannot be excluded if the bit sequences represent analogs of Gödel numbers for associations.

Does quantum non-determinism reduce to classical non-determinism for "small" state function reductions (SSFRs)?

In ZEO, the classical non-determinism does not affect the 3-surfaces nor fermionic states at the boundary of the CD. This is consistent with the identification of the non-determinism of SSFRs as classical non-determinism.

The classical Bohr orbits would be non-unique due to the classical non-determinism appearing already for the 2-D minimal surfaces. The very fact that computer programs can be realized, strongly suggests that this non-determinism is present.

There are two types of non determinisms. A non-deterministic time-like crystal (time crystal) and non-deterministic space-like crystal represent these non-determinisms. Each cell of these crystals would be a seat of non-determinism meaning that the surface branches at the locus of the non-determinism and a single branch is selected. This makes it possible to generate a conscious memory in a memory recall.

Reading and writing transform these two kinds of non-determinisms to each other.

1. Reading space-like crystals representing data bit sequence creates a time-like representation as a sequence of SSFRs if at a given moment the qubits of the geometric past are frozen. A series of SSFRs, conscious stream, "self" is created at the quantum level. Therefore a space-like non-deterministic crystal can be transformed to a time-crystal. In writing the opposite happens. The minimum energy state for the associated quantum states selects a unique configuration.

   Quantum entanglement between separate non-deterministic representations (cognitive representations possibly allowing characterization in terms of a p-adic topology for a ramified prime) is possible. Also entangled between time- and space-like non-deterministic degrees of freedom is possible.

2. How these reading and writing processes could be realized? A relation to topological quantum computation, in which time-like and space-like braidings by monopole flux tubes play a central role suggests a possible answer to the question [K3]. Think of dancers connected by threads to fixed points on the wall. Dance can be interpreted as a time-like braiding and induces space-like braiding as knotting and linking of the threads connecting the dancers. In TGD the threads correspond to monopole flux tubes.

But what does the classical non-determinism mean?

I have mentioned several times classical non-determinism at the level of holography = holomorphy principle identifying space-time surfaces as roots $(f_1, f_2) = (0, 0)$ of analytic functions of H coordinates. At the level of 3-D holographic data branching should occur so that the algebraic equations allow several roots with different tangent spaces.

1. What is the precise meaning of the analogy between holographic data as 3-surfaces and the frames of soap films? Could all roots $(f_1, f_2) = (0, 0)$ correspond to different alternatives for this non-determinism or are there some restrictions? It seems that the 4-D roots, which can be glued together continuously cannot correspond to the non-determinism. The cusp catastrophe serves as a good example of the situation. The regions of the space-time surface representing different roots cannot be regarded as distinct space-time surfaces.

   Rather, it seems that the non-determinism requires multiplicity of the 4-D tangent space and in this kind of situation one must select one branch.

2. Could the choice of only one root in the branching situation give rise to non-determinism? Is it possible to implement boundary conditions stating classical and quantal conservation laws at the interfaces of the regions corresponding to different branches?

   Any general coordinate invariant action expressible in terms of the induced geometry is consistent with holography = holomorphy principle [L122, L127] Is it permissible to choose the classical action so that boundary conditions can be satisfied when a single root is selected? This would force coupling constant evolution for the parameters of the action if one also assumes that the classical action exponential as an exponent of Kähler function corresponds to a power of the discriminant D defined as a product of root differences? The same choice should be made at the fermion level as well: the super symmetry fixing the modified fermionic gamma matrices once the bosonic action is fixed, would guarantee this.

3. Also, the roots u for a polynomial $P(u)$ of the hypercomplex real coordinate u assignable to the singularities as loci of non-determinism at the string world sheets come to mind. These roots must be real. At criticality a new root could appear. Also branching could occur and relate to the fermion pair creation possible only in 4-D space-time thanks to the existence of exotic smooth structures [L128, L127]. Could these roots represent the positions of qubits?

What could the updating of the training material by adding an association mean at a fundamental level?

Retraining cannot be only the manipulation of association probabilities but also the addition of new associations. The scope of the concept "associations related to a given input" is expanded and complexity increases.

If these associations are enumerated by bit sequences, it is enough to associate a series of bits with the new association as a classical bit sequence and to this new bit sequence a qubit sequence by bit-qubit correspondence. The superposition of the quantum counterpart of the new association with previous qubit sequences should be possible. Just like in LLM, also the combinations of the basic associations mapped to qubit sequences into longer quantum association chains should be possible.

Comparison with axons

Is it reasonable to represent the training data as an analogy to the dynamic quantum states of axons that microtubules might represent? A set of qubits related to an axon. Each set of qubits represents one association.

The axon states allowed by classical space-like non-determinism would correspond to different associations as sets of qubits, which in turn correspond to sets of bits. Data update would be by inducing thermal chaos and time reversal by means of a nerve impulse and the subsequent "reincarnation". Local thermal chaos induced by means of electric fields in the basic update operation. The local states of axons (microtubules) would be symbolic representations, kind of Gödel numbers for actions.

13.4.9 On symbolic consciousness

Whether the notion of symbolic consciousness could make sense in some sense has been a topic of discussion in our Zoom group.

1. A symbol represents an object to the observer and its meaning, if any, depends entirely on the associations that arise in the observer. A symbol is an object or process that sufficiently resembles the object it represents.

   In this sense, one cannot speak of a symbol as an independent object. Just as one cannot speak of information as something absolute. The amount of conscious information produced by a symbol depends on its observer.

2. If one had to necessarily call some form of consciousness symbolic, then I would call the consciousness presented above, possibly related to transistors and microprocessors, symbolic. In the optimal case, a program running in a microprocessor generates OH-O^- consciousness from the program as an analogy of a DNA chain, which symbolically represents a process that has meaning for us through the output.

13.5 How to associate quantum computation to classical computation

How could a classical computer become a conscious and living system? The tentative answer to this question, discussed in [L125], is that something analogous to a fusion of classical and quantum computer takes place.

In zero energy ontology (ZEO) one can say, the quantum computation would be a superposition of all possible computations with fixed initial values. This is made possible by the fact that classical physics as Bohr orbitology is an exact part of quantum physics in TGD and by the predicted slight violation of classical determinism. The computation in the usual sense would correspond to the most probable computation in the superposition.

In the sequel I consider the above question in detail.

13.5.1 Basic input from Quantum TGD

What are the basic pieces from the TGD side?

1. Zero energy ontology (ZEO) defining new quantum ontology, solving the basic problem of quantum measurement theory, is necessary. General coordinate invariance requires holography and it is not quite deterministic so that space-time surfaces are analogous to almost deterministic Bohr orbits and Bohr orbitology becomes an exact part of quantum TGD.

2. Classical non-determinism corresponds to the non-determinism of minimal surfaces: already for 2-D soap films as minimal surfaces the frames do not define the soap film uniquely. In ZEO this non-determinism makes possible a sequence of small state function reductions (SSFRs) as a counter for a sequence of measurements of the same observables which in standard QM does not change the state. In TGD the second member of the zero energy state

at the passive boundary of the causal diamond (CD) is unaffected by the second member at the active boundary is affected.This gives rise to a conscious entity, self. In "big" SFR (BSFR) the self "dies" and reincarnates with a reversed arrow of geometric time.

3. Each pulse of the computer clock is associated with the possibility of classical non-determinism of a 4-D minimal surface. Classical non-determinism would produce a superposition of 4-surfaces corresponding to different values of bit and associated qubit. Protons are also involved: protons are either ordinary or dark and located at the gravitational magnetic body. Pollack effect induces the transfer of the proton to the magnetic body and its reversal occurring spontaneously its transfer back.

4. OH-O^- qubits are an essential part of the system. For the O^- qubit, the proton of OH is at the gravitational magnetic body. Under certain conditions the gravitational magnetic body should be able to control the ordinary bits. Quantum entanglement of the ordinary and OH-O^- qubit and quantum criticality is required and would be induced by the classical non-determinism.

   If the bit's reversal energy corresponds to the thermal energy, the situation is quantum critical. This is the case also when the energies for the reversal of qubit and bit are nearly identical. This quantum criticality is controlled by the difference in the bit's reversal energies. Small energy difference corresponds to quantum criticality.

   The reversal of the second qubit reverses the bit: one can interpret the reversal for bit and qubit as an exchange of energy between the qubit and the bit. The farther away the probability for a given value of bit is from the value 1/2 the higher the determinism of the program is.

5. The magnitudes of the classical electric and magnetic fields control the energy of the bit and qubit. These are determined by classical physics for the classical space-time surface, which can be non-deterministic.

13.5.2 A concrete model for classical-to-quantum transition

What happens in ordinary computing?

A general model of classical computer is needed.

1. The first model: A tape containing program instructions is fed into a Turing machine. Depending on the command, the state of the computing unit changes. The transition of the tape corresponds to a clock pulse.

2. The second model: The program is implemented as a 1-D conveyor belt and the incoming bit configuration enters the tape and progresses along it, changing with each step. The output of the program comes out. DNA replication, transcription and mRNA translation correspond to this analogy.

Classical non-determinism

Classical non-determinism, which is the new element, can be assigned to the periods between clock pulses.

1. Thanks to classical non-determinism, the output produced by a program instruction would be a superposition of two space-time surfaces as analogs of Bohr orbits.

2. In the transition corresponding to a clock pulse, the state would be transformed to an unentangled state by a non-deterministic SSFR or a pair of BSFRs. A quantum measurement of bits would be thus performed on the outgoing superposition of bit-qubit configurations.

Concrete model

1. The network performing the computation consists of gates. A gate connects a small number of input bits to the output bits, the number of which cannot be greater than the number of input bits. This operation is statistically deterministic.

   When the input bits are fixed, the output bits are determined by dynamics as non-equilibrium thermodynamic state.

2. The clock pulse triggers the next operation. The failure of the exact classical determinism must relate to this and produce a superposition of space-time surfaces as the resulting qubit because OH and O^- correspond to different space-time surfaces, even topologically.

3. What is essential is the entanglement of the OH-O^- qubit and the ordinary bit and the measurement of the qubit in the beginning of the nex clock pulse. The outcome is not deterministic.

4. The classical bit corresponds to a voltage or current that is determined through statistical determinism in the gate. On the other hand, it corresponds to a classical electric field in a transistor or a magnetic field in a memory bit.

   The direction of this classical field is classically non-deterministic and correlates with the OH-O^- qubit. When the field changes direction, the OH-bit becomes an O^-bit or vice versa. A dark proton is transferred between the system and its gravitational magnetic body.

5. Classical non-determinism creates a superposition of OH and O^- bits. The proton resides both at the gravitational magnetic body and in OH molecules, being analogous to Schrödinger's cat.

   This induces the formation of a quantum entangled state between ordinary qubit and OH-O^- qubits. If the OH-O^- qubit and the bit are quantum entangled before the clock pulse, the quantum measurement of OH-O^- qubit or of ordinary qubit recues the entanglement and leads to a fixed bit.

Some questions

One can raise critical questions:

1. The energy transfer between a bit and a qubit resembles quantum tunnelling. I have proposed that a pair of BSFRs correspond to quantum tunnelling. It is not clear whether a single SSFR can have an interpretation as quantum tunnelling. Could the measurement of a qubit correspond to a single SSFR or to two BSFRs?

2. What could be the energetic role of the clock pulse?

   The system under consideration would be a clock photon + bit + qubit and the total energy would be conserved.

   (a) Could the clock pulse have a role of a catalyst, providing the energy needed for quantum tunnelling. In a qubit measurement, energy can be transferred between the bit and the qubit, but the total energy is conserved. The clock photon would kick the system over the potential barrier and then be emitted back into the field.

   (b) Or does the clock photon transfer energy to or from the bit + qubit system? Could the energy of the photon associated with the pulse frequency correspond to the energy difference for a bit and a qubit.

   The typical frequency of computer clock is few GHz. 1 GHz would correspond to an energy $E = .4 \times 10^{-5}$ eV and wavelength $\lambda \simeq .75$ m. At the surface of the Earth, the gravitational binding energy of a proton is about 1 eV. The energy E eV can raise the proton to the height $h \sim .4 \times 10^{-5} R_E \sim 25.6$ m.

13.6 Quantum version for the associative learning in large language models

In the TGD framework the model for associative learning, as it is modelled in large language models (LLMs), could be generalized to formulate a quantum model for associative learning as it could occur in TGD inspired theory of consciousness.

I have discussed LLMs from TGD point of view in [L105, L106, L127]. One could also consider the combination of the TGD inspired quantum version of associative learning with the speculative idea of extending a classical computer to a hybrid of classical and quantum computers [L125].

13.6.1 Zero energy ontology from the point of view of LLMs

Zero energy ontology (ZEO) is the first piece of the TGD vision.

1. By holography, spacetime surfaces are analogous to Bohr orbits as basic objects. This means that 3-D structure as 3-surface determines almost deterministically the 4-surface.

   The failure of a complete classical determinism is essential. The non-deterministic classical time evolution involves 3-D loci of non-determinism as analogs of 1-D frames of 2-D soap films.

   Different Bohr orbits starting from a fixed 3-surface A at the passive boundary of CD would lead to different surfaces B located at the active boundary of CD whose size of CD would increase during the sequence of SSFRs.

2. At the quantum level, the superpositions of Bohr orbits define zero-energy states in geometric degrees of freedom ("world of classical worlds", WCW). In fermionic degrees of freedom zero energy states are superpositions of products of fermionic states assignable to the boundaries of CD and to the loci of non-determinism.

   The 3-D state at the passive boundary would remain invariant under the sequence of "small" state function reductions (SSFRs). This is the TGD counterpart of the Zeno effect.

3. The Bohr orbits of a 3-D particle are analogous to random walks $A \rightarrow B$ for a particle as a 3-surface. The almost deterministic Bohr orbits $A \rightarrow B$ are analogous to the association sequences of language models associated with the many layered neural nets.

   The non-deterministic classical time evolution is modellable by a diffusion equation (diffusion) or Schrödinger type equation (dispersion). This process would be the quantum counterpart for the diffusion appearing in LLMs [A23] (see this). Whether this process could be seen as an analog of a path integral defined as a sum over a discrete set of paths as Bohr orbits, is an interesting question.

4. The time reversal of the diffusion/dispersion is used in error correction in LLMs and in ZEO it could correspond to a pair of BSFRs involving a temporary change of the arrow of time. A pair of BSFRs would make it possible for the system to make a fresh start and therefore to learn by trial and error. This is perhaps the most important aspect of conscious intelligence.

5. On the quantum level, a series of SSFRs corresponds to a subjective time evolution giving rise to a conscious self. It also corresponds to an analog of computation and of mathematical reasoning: the theorem develops step by step as a sequence of SSFRs. In biology this sequence corresponds to biological function and in neuroscience to a behavioral pattern.

13.6.2 Holography =holomorphy hypothesis and learning process

Holography=holomorphy hypothesis allows to reduce classical field equations to purely algebraic conditions $(f_1, f_2) = (0, 0)$, where f_i are analytic functions of one hypercomplex and 3 complex coordinates of $H = M^4 \times CP_2$. The solutions are minimal surfaces irrespective of the classical action as long as it is general coordinate invariant and expressible in terms of induced geometry. This means universality of the dynamics and is quantum criticality expressed by the holomorphy.

This implies saddle surface property for the spacetime surface meaning that the real parts of f_i do not have minima or maxima in general.

Interestingly, the almost absence of minima meaning a saddle point property for most extrema is essential for the success of LLMs, which is in fact not well-understood. In LLMs, the cost function V measuring the size of the teaching error, is minimized in the parameter space by gradient dynamics. If most extrema are saddle points, the process does not get stuck to a local minimum and learning becomes very effective.

Furthermore, in LLMs local flatness of the parameter space is of help since it increases the probability that the gradient dynamics leads to the minimum and also reduces the probability to leave the minimum by a small perturbation.

Could the minimal surface property prevent the sticking in the recent case?

1. It is useful to consider the situation first at the level of a single space-time surface (rather than WCW). At the space-level all points are geometrically saddle points in the geometrical sense by the minimal surface property stating that the trace of the second fundamental form, as an analog of acceleration identifiable as a sum of external curvatures, vanishes. Note that this is not equivalent with saddle point property of minima for functions.

2. The quantum learning process would occur in the "world of classical worlds" (WCW) as the space of Bohr orbits rather than at the space-time level. The loss function is in TGD replaced by the vacuum functional as an exponent of the classical action proposed to have by the analog of Langlands duality also purely number theoretic expression, which would mean computability and enormous simplification [L123].

   The Kähler function K, defining vacuum functional as its exponential, is in a central role. Also the degeneracies of the maxima are important. The maxima for the exponential of Kähler function are thermodynamic analogs for Boltzmann exponents and their degeneracy measured by entropy. One can say that the minimization of energy and maximization of entropy compete.

   Note that K is determined only modulo addition of a real or imaginary part of a holomorphic function of WCW complex coordinates. The Kähler metric of WCW is of the form $G_{M\overline{N}} = \partial_M \partial_{\overline{N}} K$.

   The maxima of vacuum functional $exp(K)$, which correspond to minima of the Kähler functio, are of special interest. The Euclidian signature puts strong constraints at the minima of K. Criticality condition means that some second partial derivates of K with respect to the real coordinates vanish.

   A good example is the metric of complex plane given by $dzd\overline{z} = d\rho^2 + \rho^2 d\phi^2$ and has $K = z\overline{z} = \rho^2$ having a minimum at origin. The metric is flat.

3. It must be however made clear that in the learning the loss function would measure the deviation of B_2 from B_1 and cannot be identified as K. There are two minimization problems involved and it is not clear whether they are consistent.

The notion of finite measurement resolution

Finite measurement resolution is a key notion in TGD. There are two views of finite measurement resolution based on geometry and number theory respectively. These views are dual.

1. The geometric view relies on inclusions of hyperfinite factors [K110]: the included factor is analogous to a gauge group leaving the observed physics invariant: this view of finite measurement resolution is central in the geometric view of TGD.

2. The second view is based on number theoretic discretization citebtartFrenkel,compuTGD. The geometric inclusion hierarchies correspond naturally to number theoretic inclusions hierarchies for the extensions of rationals. Space-time surface for which polynomials defining it are in an extension E of rationals allows in a natural way a discretization as points, which are in E. The points of the discretization can be also regarded as points in an extension of p-adic numbers induced by E. I call these discretizations cognitive representations and they form a hierarchy corresponding to extensions of rationals.

This leads to a p-adic description of cognition. One obtains a unique number-theoretical representation for discretization and it leads to a generalization of the Turing paradigm [K40]: rational numbers are replaced by complexity hierarchies of their extensions and one ends up with number-theoretical computationalism. This gives complexity hierarchies for space-time surfaces as Bohr orbits and they correspond to an improving resolution of discretization and are realized as polynomial hierarchies.

Holography suggests that for the minimal option the number theoretic discretization applies only to the loci of the classical non-determinism for the space-time surface as minimal surfaces. These loci define the seats of conscious memories and would be 3-D analogs of 1-D frames spanning 2-D soap films.

3. The complementary nature of geometric and number theoretic views of TGD leads to a 4-D generalization of Langlands duality [L122, L127]. This adds powerful constraints also to the quantum model of associative learning.

4. The concept of complexity, which closely relates to evolution, reduces to number theory. Higher-level learning could be seen as a transition to a higher level of complexity and would be something to realize in conscious quantum learning. Complexity hierarchies correspond to polynomial hierarchies represented as space-time surfaces.

13.6.3 A model for the learning process

How could the learning process take place?

1. Learning process can be seen mathematically as a construction of a representation for the dynamics of the external world by a subsystem. Associations $A_1 \to B_1$ for the dynamics of the external world serve a teaching material and a representation as for these as associations $A \to B$ in the internal model world is constructed as a model for the dynamics external world.

   One can assume that the external world states $A_1 \to B_1$ actually correspond to the sensory percepts of the states of the external world and in the learning process the system learns to associated B_1 with A_1 process in which the difference between B and B_1 is minimized.

   In the TGD based model for sensory perception [K114] [L63] as construction of standardized mental images, the feedback loop between sensory organs and magnetic body would make this possible in the same way as in pattern recognition. The deviation of B from B_1 is minimized. This deviation would define the virtual sensory input from the magnetic body to the sensory organ.

   Classically A and B (A_1 and B_1) correspond to 3-surfaces at the boundaries of a CD and A (A_1) is fixed in ZEO. At the quantum level, one has zero energy states as superpositions of orbits $A \to B$ ($A_1 \to B_1$).

2. The parameters characterizing the space-time surfaces, identifiable as the Taylor coefficients of the analytic functions and in the special case of polynomials, define the counterpart of the latent space (see this and this). The coefficients belong to an extension E of rationals and one obtains a hierarchy of extensions having interpretation in terms of evolution [L122, L123, L104]. The coefficients determine almost deterministically the space-time surface as a Bohr orbit.

   The failure of non-determinism corresponds to the 3-D loci of non-determinism at the Bohr orbit of A and the discrete variables parametrizing the non-determinism correspond to the parameter space of LLMs.

   The space of 3-surfaces at the passive or active boundary of CD would correspond to the latent space as a subspace of the space of features (see this). The cutoff to the degree of the polynomial and to the dimension of the Galois group of the polynomial would induce the analog of dimensional reduction replacing the feature space with a latent space. This cutoff would also reduce the parameter space as the discrete space characterizing the classical non-determinism. The TGD counterpart of the loss landscape (see this) corresponds to a subspace of the parameter space.

As the size scale CD increases, the size of the loss landscape increases. Also the complexity of the extension E of rationals associated with the polynomials (P_1, P_2) defining the spacetime surfaces as their roots correlates with the size of the loss landscape.

3. A fixed 3-surface at the initial moment at the passive boundary of the CD corresponds to A in the association $A \to B$. This choice determines the coefficients of the polynomial that defines the latent space. The correspondence $A \to A_1$ could be also learned in the learning process. This correspondence should determine the correspondence $B \to B_1$. The non-uniqueness of B due to classical non-determinism makes possible many associations.

   The construction of a representation means finding non-deterministic space-time surfaces $A \to B$ in CD producing an optimal representation for the pair $A_1 \to B_1$, meaning that B is as near as possible B_1. The error function measures the deviation of B from B_1. In LLMs the error function is minimized by a gradient method. The counterpart ot his method in the the case of the construction of conscious association should be understood.

The fact that the TGD Universe is fractal is expected to help considerably the construction of conscious associations as representations.

1. The representation could be seen as a simplified version of the original obtained by scaling the size of the cd, either up or down.

2. The reduction of the degree of polynomials used and the algebraic dimension of extension E reduce the complexity. The restriction of an extension of E to E reduces complexity and the hierarchies of extensions of E define complexity hierarchies.

3. Also the hierarchies of analytic maps of $(f_1, f_2) \to (g_1(f_1, 2_2), g_2(f_1, f_2))$ define iteration hierarchies analogous to those associated with fractals and approach to what looks like chaos. One can also "imagine" more complex systems at the level of representation by extending E or performing these iterations.

13.6.4 The version of the learning model for quantum versions of classical computers

One can formulate this picture also in the speculative vision [L125] in which a classical computer becomes a living system as a hybrid of classical and quantum computers.

1. A quantum computation-like process would be associated with classical computation. The classical non-determinism could be maximal in the sense that each tick of the computer clock would involve loci of classical non-determinism making the outputs of the gates non-deterministic.

   Classical computation would correspond to the most probable Bohr orbit in the representation of the computation as a zero energy state. If localization in WCW is possible (position measurement in the discrete degrees of freedom of WCW due to non-determinism) this localization could occur at a single Bohr orbit.

2. The output of a gate would be a superposition of pairs of ordinary bits and $OH - O^-$ qubits. For the $OH - O^-$ qubits, the proton of OH would be transformed to a gravitationally dark proton at the gravitational magnetic body of the Earth or the Sun. This entanglement would be reduced in an SSFR which could, but need not, occur after each clock period.

3. This would give rise to a computational analog of the associative learning process in which the learning process assigns to the pairs $A_1 \to B_1$ computations $A \to B$. Note that classical non-determinism also makes possible the formation of association sequences.

13.6.5 Conscious associative learning as an analog of sensory perception and motor action

Holography, together with the TGD based view of sensory perception [L27], suggests that the conscious associative learning process has a lot of common with sensory perception in a 4-D sense.

In the TGD framework, motor action could be seen as a time reversal of sensory perception. Motor action could involve a pair of BSFRs inducing a quantum tunnelling from a configuration of muscles to a new configuration so that same basic mechanism but with a reversed arrow of geomeric time could be involved. Intention for the motor action should relate to the process of building a sensory perception as a sequence of SSFRs in a reversed time direction.

1. In ZEO, sensory perception at the classical level would not be 3-D surface, but a 4-D space-time surface, an almost deterministic classical time evolution representing association $A_1 \to B_1$. In the case of hearing this is rather obvious but for vision the time scale is so short that the percept looks like time= constant snapshot. Actually the geometric time duration assignable to the visual percept or order .1 seconds.

   The association $A \to B$, one might perhaps speak of cognitive representation, is realized at the magnetic body (MB) of the brain as a representation of $A_1 \to B_1$. $A \to B$ is generated in a stepwise learning process. The goal is to construct a standardized mental image consisting of familiar objects consisting of standard features.

   The difference between $A \to B$ and $A_1 \to B_1$, rather than only the difference between B and B_1, is minimized. The sequence of SSFRs keeps A fixed. A pair of BSFRs changes also A: this makes possible a trial and error process in which one starts from scratch, so to say.

2. Sensory organ serves as a kind of screen, both for the sensory input arriving from the external world and for the virtual sensory input from MB. The sensory input is analyzed by the brain to features in various scales and the features are sent to the magnetic body. At the MB, the features in various scales are compared to standard features and those minimizing the difference is selected.

3. The selected features determine the virtual sensory as a slight amplification of the contribution of the selected features. The step *sensory organ* $\to$ *brain* $\to$ *MB* $\to$*...* is repeated until the total sensory input at the sensory organ does not change anymore. The original percept $A_1 \to B_1$ is affected in the process and eventually replaced with $A \to B$ at the level of the sensory organ. In this respect the process differs from the associative learning.

   If the signals from the brain to MB and back are realized as dark photons (, which can decay to ordinary photons identifiable as biophotons), the process is so fast that the process can converge in a reasonable time.

4. The outcome is not realistic but essentially an artwork. It must be so since $A_1 \to B_1$ is very noisy so that both $A_1 \to B_1$ and $A \to B$, can be only guesses for what really happened. For instance, people who are physiologically blind and get back their vision, can see only diffuse light since they have not learned this process in childhood. This suggests that temporary time reversals as analogs of the time reversed diffusion play changing A play an essential role. Note BSFRs could mean a position measurement in the space of Bohr orbits selecting a single Bohr orbit and is analogous to time reversed diffusion.

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Index